NOTE

This Microfiche meets the quality requirements of the American National Standard for Microfiche of Documents (ANSI PH5.9-1975). However, because of imperfections in the document from which it was made, it contains images that are illegible or difficult to read. The source document for this microfiche is the best copy that could be obtained prior to filming

CIS

Congressional Information Service, Inc.
Washington, D.C.

Western Surface Mine
Permitting and Reclamation

Volume II-Contractor Documents

Part A: Soil and Overburden Management in Western Surface Coal Mine Reclamation

Revegetation Technology and Issues at Western Surface Coal Mines

Wildlife Technologies for Western Surface Coal Mining

Office of Technology Assessment
July 1986

These Contractor Documents were prepared by outside contractors as an input to an OTA assessment. They do not necessarily reflect the analytical findings of OTA, the Advisory Panel, or the Technology Assessment Board.

J952-69

SOIL AND OVERBURDEN MANAGEMENT IN WESTERN SURFACE COAL MINE RECLAMATION

August 28, 1985

Prepared for:

Jenifer Robison
Office of Technology Assessment
Congress of the United States
Energy and Materials Program
Fourth Floor
600 Pennsylvania Avenue, S.E.
Washington, D.C. 20003

Prepared by:

James P. Walsh

Registered Soil Scientist
ARCPACS # 2002
Registered Geologist
State of Califronia # 3491

TABLE OF CONTENTS

Section — Page

1.0 INTRODUCTION . . . 1-1
1.1 Purpose . . . 1-1
1.2 Scope . . . 1-2
1.3 Methods . . . 1-4
  1.3.1 Overview. . . . 1-4
  1.3.2 Case Studies. . . . 1-4
  1.3.3 Analysis. . . . 1-5
  1.3.4 Issues . . . 1-5
1.4 Background . . . 1-5

2.0 OVERVIEW . . . 2-1
2.1 Published and Unpublished Sources of Data . . . 2-1
  2.1.1 SCS Soil Survey Reports. . . . 2-1
  2.1.2 U.S. Geological Survey and Other Sources. . . . 2-3
2.2 Baseline Data Collection and Analytical Techniques . . . 2-3
  2.2.1 Site-Specific Soil Inventories. . . . 2-3
  2.2.2 Soil Analyses. . . . 2-4
  2.2.3 Geology Description. . . . 2-9
  2.2.4 Overburden Drilling and Sampling. . . . 2-9
  2.2.5 Overburden Sample Analysis. . . . 2-12
2.3 Reclamation Planning and Techniques . . . 2-14
  2.3.1 Criteria for Soil Use. . . . 2-14
  2.3.2 Overburden Characterization and Delineation of Deleterious Strata. . . . 2-19
  2.3.3 Overburden Handling. . . . 2-22
  2.3.4 The Recontoured Surface. . . . 2-25
  2.3.5 Soil Handling. . . . 2-27
  2.3.6 Special Soil Reconstruction. . . . 2-29
  2.3.7 Supplemental Soil Materials . . . 2-30
2.4 Methods for Predicting Reclamation Success . . . 2-31
  2.4.1 Compliance. . . . 2-31
  2.4.2 Spoil Quality and Redressed Soil Thickness. . . . 2-31
  2.4.3 Revegetation Success. . . . 2-34
2.5 Soil and Overburden Reclamation Success and Bond Release Criteria . . . 2-36
  2.5.1 Recontoured Spoil. . . . 2-36
  2.5.2 Reconstructed Soil Profiles. . . . 2-36
2.6 Soil and Spoil Monitoring . . . 2-37
  2.6.1 Recontoured Spoil. . . . 2-38
  2.6.2 Reconstructed Soils. . . . 2-38
2.7 Comparison of State and Federal Programs . . . 2-39
  2.7.1 Comparison of Acts. . . . 2-40
  2.7.2 Comparison of Regulations and Guidelines. . . . 2-43

3.0 CASE STUDIES . . . 3-1
3.1 Case Study A . . . 3-1
  3.1.1 Introduction . . . 3-1
  3.1.2 Soil Inventory . . . 3-2
  3.1.3 Baseline Overburden Investigation . . . 3-3
  3.1.4 Overburden Handling . . . 3-3

Section Page

3.1.5 Soil Handling 3-3
3.1.6 Prime Farmland 3-4
3.1.7 Special Soil Reconstruction 3-4
3.2 Case Study B 3-5
3.2.1 Introduction 3-5
3.2.2 Soil Baseline Studies 3-6
3.2.3 Overburden Baseline Studies 3-6
3.2.4 Soil Handling 3-6
3.2.5 Land Use 3-7
3.2.6 Recontoured Landscape 3-8
3.2.7 Standards of Reclamation Success 3-8
3.2.8 Monitoring 3-9
3.3 Case Study C 3-9
3.3.1 Introduction 3-9
3.3.2 Baseline Overburden 3-9
3.3.3 Soil Inventory 3-10
3.3.4 Interburden Special Handling 3-10
3.3.5 Bluff Extension 3-11
3.3.6 Recontoured Spoil Sampling 3-12
3.3.7 Soil Handling 3-13
3.3.8 Special Soil Reconstruction 3-14
3.3.9 Soil Volume Accounting 3-14
3.4 Case Study D 3-15
3.4.1 Introduction 3-15
3.4.2 Baseline Geologic Information 3-15
3.4.3 Baseline Soil Inventory 3-16
3.4.4 Two Lift Topsoil Handling 3-16
3.4.5 Overburden Handling 3-17
3.4.6 Monitoring and Bond Release Criteria 3-17
3.5 Case Study E 3-12
3.5.1 Introduction 3-18
3.5.2 Baseline Overburden 3-19
3.5.3 Soil Inventory 3-20
3.5.4 Soil Quality Versus Topsoiling Depth 3-20
3.5.5 Topsoil Handling 3-20
3.5.6 Overburden Handling 3-21
3.5.7 Land Use 3-22
3.6 Case Study F 3-14
3.6.1 Introduction 3-22
3.6.2 Baseline Overburden Characterization 3-23
3.6.3 Baseline Soil Inventory 3-23
3.6.4 Overburden Handling 3-24
3.6.5 Recontoured Spoil Sampling 3-24
3.6.6 Soil Handling 3-25
3.6.7 Research 3-26
3.7 Case Study G 3-26
3.7.1 Introduction 3-26
3.7.2 Soil Inventory 3-27
3.7.3 Baseline Overburden Characterization 3-28
3.7.4 Delineation of Deleterious Strata 3-29
3.7.5 Special Overburden Handling 3-30
3.7.6 Topsoil Handling 3-30

Section Page

3.7.7 Research and Monitoring 3-31
3.7.8 Post-Mining Landscape 3-31
3.8 Case Study H 3-31
3.8.1 Introduction 3-32
3.8.2 Baseline Overburden Investigation 3-33
3.8.3 Soil Inventory 3-33
3.8.4 Topsoil Handling 3-34
3.8.5 Overburden Handling and Recontoured Spoil Sampling 3-34
3.8.6 Intensity of Drill Hole Spacing 3-36
3.8.7 Excess Spoil 3-36
3.9 Case Study I 3-37
3.9.1 Intorduction 3-37
3.9.2 Baseline Overburden Characterization 3-37
3.9.3 Soil Inventory 3-38
3.9.4 Topsoil Handling 3-38
3.9.5 Deleterious Overburden Management 3-39
3.9.6 Reclamation Results 3-40
3.10 Case Study J 3-41
3.10.1 Introduction 3-41
3.10.2 Overburden Characterization 3-42
3.10.3 Soil Inventory 3-42
3.10.4 Soil Handling 3-43
3.10.5 Overburden Handling 3-44
3.10.6 Land Use 3-44
3.10.7 Monitoring 3-44
3.11 Case Study K 3-44
3.11.1 Introduction 3-44
3.11.2 Baseline Overburden 3-45
3.11.3 Soil Baseline Inventory 3-45
3.11.4 Soil Handling 3-46
3.11.5 Excess Overburden 3-46
3.11.6 Land Use 3-46
3.12 Case Study L 3-47
3.12.1 Introduction 3-47
3.12.2 Soil Inventory 3-48
3.12.3 Baseline Overburden Characterization 3-48
3.12.4 Cover Over Toxic Materials 3-49
3.12.5 Topsoil Inventory Evaluation 3-49
3.12.6 Regolith Study 3-50
3.12.7 Topsoil Handling 3-50
3.13 Case Study M 3-51
3.13.1 Introduction 3-51
3.13.2 Baseline Overburden 3-52
3.13.3 Baseline Soils Inventory 3-53
3.13.4 Reclamation Plan 3-53
3.13.5 Approximati Original Contour 3-54
3.13.6 Land Use 3-55
3.13.7 Reclamation Practice 3-56
3.13.8 Research 3-56

Section Page

4.0 ANALYSIS 4-1
4.1 Databases 4-2
  4.1.1 Soil Databases. 4-2
  4.1.2 Overburden Data Bases. 4-2
4.2 Baseline Data Collection and Analytical Techniques 4-4
  4.2.1 Soil Inventory and Evaluation. 4-4
  4.2.2 Overburden Drilling, Description, Sampling. 4-9
  4.2.3 Acid, Alkaline and Toxic Forming Overburden. 4-14
4.3 Reclamation Techniques 4-20
  4.3.1 Soil Handling. 4-20
  4.3.2 Overburden Handling. 4-26
  4.3.3 Land Use and Topography. 4-29
4.4 Models for Predicting Reclamation Success 4-32
  4.4.1 Available Quantitative Models 4-33
  4.4.2 Uncertainties. 4-34
4.5 Evaluation of Reclamation Success and Bond Release 4-34
  4.5.1 Reconstructed Soils. 4-34
  4.5.2 Recontoured Overburden. 4-36
4.6 Soil and Spoil Monitoring 4-37

5.0 ISSUES 5-1
5.1 Innovation, Ecologic Variability and Regulatory Flexibility . . 5-2
  5.1.1 The Need for Innovation. 5-2
  5.1.2 Innovative Practices. 5-4
5.2 Operator Attitude and Regulatory Control 5-4
5.3 Findings of Reclaimabilty 5-7
  5.3.1 Problems in the Affirmative Demonstration of Reclamation. . 5-7
  5.3.2 Permit Approval and Reclaimability. 5-9
5.4 Reclamation Success, Soil Monitoring, and Bond Release 5-11
5.5 Research 5-12
  5.5.1 Current Research. 5-12
  5.5.2 Research Needs. 5-14

6.0 CONCLUSIONS 6-1
6.1 Databases 6-1
6.2 Baseline Data Collection and Analytical Techniques 6-1
  6.2.1 Soil Inventory and Evaluation 6-1
  6.2.2 Overburden Drilling, Description, Sampling. 6-2
  6.2.3 Acid, Alkaline and Toxic Forming Overburden. 6-3
6.3 Reclamation Techniques 6-5
  6.3.1 Soil Handling. 6-5
  6.3.2 Overburden Handling. 6-7
  6.3.3 Land Use and Topography. 6-8
6.4 Models for Predicting Reclamation Success 6-8
6.5 Evaluation of Reclamation Success and Bond Release 6-9
  6.5.1 Reconstructed Soils. 6-9
  6.5.2 Recontoured Overburden. 6-10
6.6 Soil and Spoil Monitoring 6-10
6.7 Comparison of State and Federal Programs 6-11
  6.7.1 Comparison of Acts. 6-11
  6.7.2 Comparison of Regulations and Guidelines. 6-11
6.8 Innovation, Ecologic Variability and Regulatory Flexibility . . . 6-12

Section Page
6.8.1 The Need for Innovation. 6-12
6.8.2 Innovative Practices. 6-13
6.9 Operator Attitude and Regulatory Control 6-13
6.10 Findings of Reclaimabilty 6-14
6.10.1 Problems in the Affirmative Demonstration of Reclamation. 6-14
6.10.2 Permit Approval and Reclaimability. 6-15
6.11 Reclamation Success, Soil Monitoring, and Bond Release 6-15
6.12 Research 6-16
6.12.1 Current Research. 6-16
6.12.2 Research Needs. 6-17

REFERENCES CITED

GLOSSARY

FIGURES AND TABLES

Figures

2.1-1 Criteria for Identifying Kinds of Soil Surveys 2-2
2.2-1 Soil Map Unit Description 2-5
2.2-2 Soil Pedon Description 2-6
2.2-3 Soil Map Legend and Portion of Soil Map 2-7
2.2-4 Typical Soil Analysis Report 2-8
2.2-5 Stratigraphic Column 2-10
2.2-6 Highwall Map and Sampling Locations 2-11
2.2-7 Geologic Log 2-13
2.3-1 Weighted Topsoil Quality Evaluation 2-17
2.3-2 Topsoil Volume Summary 2-18
2.3-3 Map of Deleterious Overburden Areas Showing 2-23
Unsuitable Parameters 2-18
2.4-1 Soil Quality, Spoil Quality, Topsoil Thickness Model 2-35
4.2-1 Geologic Cross Section Showing Stratigraphic Correlations . . 4-12
4.2-2 Plot of Lead Concentration versus Depth 4-13
4.3-1 Colorado Guide for Placement of Soils into Capability Classes 4-30

Tables

2.3-1 Topsoil Unsuitability Criteria by State 2-15
2.3-2 Overburden Unsuitability Criteria by State 2-20
2.4-1 Summary of Some Topsoil Depth Research 2-32
2.7-1 Selected Differences Between Federal and State Surface Mining Reclamation Acts 2-41
2.7-2 Selected Requirements for Baseline Studies from Regulations and Guidelines 2-44
2.7-3 Summary of Selected Performance Standards from Regulations . . 2-48
4.2-1 Results of a Round-Robin Soils Tests 4-6
4.2-2 Topsoil Salvage Depths by Series for Ten Surface Coal Mines in the Eastern Powder River Basin of Wyoming 4-8
5.1-1 List of Innovative Practices at Case Study Mines 5-5
5.5-1 Research Objectives 5-15

1.0 INTRODUCTION

This study describes soil and overburden management in reclamation of western surface coal mines. It was conducted to assist the Congress of the United States - Office of Technology Assessment (OTA) in their review of environmental protection of federal coal lands. The study is based on a review of the literature, permit applications, state and federal acts, regulations and state guidelines, as well as interviews with the regulatory authorities, environmental managers, staff scientists, researchers, and environmentalists. The study was conducted by James P. Walsh and Associates, Inc. under contract to the U.S. Congress, Office of Technology Assessment; Jenifer Robison of the OTA Energy and Materials Program was the Project Director.

1.1 Purpose

The purposes of this study are to:

- describe the data and analytical techniques used in the baseline chacterization of soil and overburden resources;
- evaluate the use of that information in reclamation planning;
- describe the methods used by the regulatory authorities in evaluating reclamation plans;
- determine if the baseline data accurately predict the conditions found during mining;
- describe reclamation monitoring and the criteria for reclamation success;
- evaluate the effectiveness of the regulatory programs; and
- suggest alternatives for resolving uncertainties and improving the process.

The report is divided into four main sections: overview, case studies, analysis, and issues. In the overview (section 2.0), soil and overburden management in reclamation is described briefly. The sources of information, methods and analytical techniques, and reclamation practice are described. Methods used by the regulatory authority to evaluate the proposed reclamation plan and to evaluate the success of spoil handling and topsoil reconstruction, as well as long term reclamation monitoring also are described. The state and federal programs are also compared.

In the 13 case studies (section 3.0), the soil and overburden management process is described from baseline data collection to bond release. Sources and use of baseline data, soil inventories and overburden drilling programs, laboratory analyses, overburden handling, soil reconstruction, resolution of special problems, criteria of reclamation success and monitoring are discussed for each case study mine.

In the analysis (section 4.0), the state of the art as described in the overview (section 2.0) is compared to the actual practice as described in the case studies (section 3.0). This section evaluates the uncertainties in the reclamation process. The major issues identified during the course of this study are presented in section 5.0; they are the the effects of regulatory control on innovation, operator attitude and regulatory authority control, the findings of reclaimability during permit approval, the evaluation of long-term reclamation success and bond release, and the current state of research and research objectives.

1.2 Scope

This study addresses soil and overburden management at western surface coal mines. Soil is the collection of natural bodies on the earth's surface, in places modified or even made by man of earthly materials, containing living matter and supporting or capable of supporting plants (USDA, Soil Conservation Service 1975). Overburden refers to material of any nature, consolidated or unconsolidated, that overlies a deposit of useful material, ore, or coal, especially those deposits mined from the surface by open cuts (American Geological Institute 1962). As used in this study, soil refers to the unconsolidated material from the surface to the first stratum of weathered bedrock and the term overburden excludes the soil. Overburden is used generically to refer to strata overlying or between coal seams unless it is used with the term interburden, in which case overburden refers to the strata above the highest coal and interburden refers to the strata between coal seams to be mined. Topsoil refers to the surface layers of a natural soil or any materials used as a soil topdressing over recontoured spoil, a useage consistent with the terminology of the law.

Management of the soil and overburden resources at a mine is a multi-step process involving soil inventories and overburden drilling, analyses of soil and overburden samples, evaluation of the analytical test results, decisions on handling of the beneficial soils and deleterious strata, implementation of the handling plans, evaluation of the results, and monitoring the reconstructed soil/overburden/landscape for the long term.

The study area comprises North Dakota, Montana, Wyoming, Colorado, and New Mexico. Most of the mines involve federal land and all were permitted under approved state permanent regulatory programs, as per the Surface Mining Control and Reclamaton Act, Public Law 95-87, referred to here as SMCRA.

Thirteen case study mines were selected to be representative of the great ecologic, geologic, and pedologic differences between mines in the study area. Every mine (but one) has unique soil and overburden problems, that are being solved on a site specific basis. The one exception is a mine chosen to be representative of a benign soil and overburden condition, a situation difficult to find.

1.3 Methods

1.3.1 Overview. This section of the report is based on mostly recent (post 1978) literature, and interviews with persons involved in reclamation. The National Technical Information Service, Government Printing Office and Enviroline bibliographic data bases were searched and the pertinent citations were reviewed.

1.3.2 Case Studies. The case studies were selected based on recommendations of the state regulatory authorities and environmental groups, and the literature review. A few mines were disqualified to avoid professional conflicts of interest.

The case study analysis began with a thorough review of the permit applications on file at the Office of Surface Mining (OSM) in Denver, or the state agencies. The soil and overburden baseline studies, reclamation plans, state decision documents, and annual reports (if any) were reviewed. The staff soil scientists or environmental coordinators for the mines were interviewed, most by telephone, and a few in person. Two mine site visits also were conducted. The OSM and state regulatory agencies were visited and the soil scientists and/or administrators responsible for permitting were interviewed regarding the state and federal programs and the specific case study mines.

The case studies are identified only by a letter, although persons familiar with the coal mines in a particular region may be able to recognize the operation from the case study description. Letters are used to identify the mines rather than names, to emphasize that the purpose of this report is not to assess the adequacy or inadequacy of the reclamation at any particular mine, but to illustrate the process under the current regulatory and scientific framework.

1.3.3 Analysis. The analysis of the uncertainties in the soil and overburden management process is based on the literature, case studies and interviews. Where there are conflicting opinions on these subjects they are presented where possible. This section is more subjective than the overview and case studies sections of the report, and the author's opinion is also presented (and represented as such).

1.3.4 Issues - The assessment of issues is based on the literature review, review of state and federal acts, rules and regulations, guidelines, permit applications, and interviews with researchers, regulatory authority and industry staff. This section is the most subjective of the report.

1.4 Background

On 3 August 1977, President Carter signed the Surface Mining Control and Reclamation Act, a complex and controversial law that passed after seven years and two presidential vetos. The two principal goals set forth in SMCRA are to protect the nation from adverse social and environmental impacts related to surface mining of coal and to assure the production of coal essential to the nation's energy supply. SMCRA created the Office of Surface Mining.

A comprehensive Federal Coal Leasing Program was instituted in 1979 and the first lease sales under the new program were held in 1981 and 1982. In 1982 and 1983, the Department of the Interior revised the regulations implementing the program to reflect a departmental shift in policy (OTA 1984). At about the same time, the department set about to redirect the implementation of SMCRA. The Office of Surface Mining was reorganized to enlarge state discretion and flexibility, to provide a "state window" and to direct enforcement toward performance standards rather than design standards. As a result of this reorganization, fewer Notice of Violations and Cessation orders were issued, reflecting a more cooperative attitude between regulators and the regulated. However, the reorganization created more controversy.

In 1984, the Office of Technology Assessment conducted an assessment of the controversy surrounding the implementation of the environmental protection aspects of the Federal Coal Leasing Program (OTA 1984). The study limited its scope to the leasing program. This study will focus on environmental protection through permitting, reclamation, and reclamation monitoring, and is being conducted by OTA at the request of the chariman of the House Interior and Insular Affairs Committee.

Many of the findings and recommendations of the OTA assessment (1984) are pertinent to the scope of this study. OTA found that the planning and leasing decisions have been based on inadequate data; an objective of this study is to recommend ways of improving the quality and accessibility of the existing data bases. OTA found that regulatory standards for determining the adequacy of the data were eliminated; an objective of this study is to suggest methods of establishing such standards. OTA found that decisions about acceptability were being deferred from leasing to permitting; an objective of this study is to see if such deferrals present problems in the permitting process, and to determine whether decisions also are being postponed in the permitting stages because of inadequate data. In the leasing process there are no unsuitability criteria based explicity on reclaimability, but the requirement to affirmatively demonstrate that issue is the responsibility of lessee in the permitting stage. OTA found that permitting agencies are more likely to impose mitigation requirements than to exclude areas from mining and an objective of this study is to identify the uncertainties in models used to evaluate the likelihood of reclamation success.

The Technology Assessment Act of 1972 requires OTA to secure for the U.S. Congress "competent, unbiased" assessments of current technology, identify alternative technological methods, identify alternative programs, make estimates and comparision of the impacts of alternative methods and programs, and identify areas of additional research needs. In this study, every effort has been made to be responsive to those goals.

2.0 OVERVIEW

Section 2.0 is a summary of techniques used by industry and the regulatory authorities to manage the soil and overburden resources for the reclamation of western surface coal mines. Baseline soil and overburden data collection, analysis of the data, incorporation of the data into the mine/reclamation plan and soil and overburden handling during reclamation are described. The techniques used by the regulatory authority to evaluate the reclamation plan and monitor it's success are also described.

2.1 Published and Unpublished Sources of Soil and Overburden Information

2.1.1 SCS Soil Survey Reports. In the case studies reviewed, Soil Conservation Service (SCS) soil surveys are the principal source of soil information available from the literature. The SCS surveys contain soil maps, map units, series and typical pedon descriptions, soil classifications and limited chemical and physical data. The SCS surveys typically are more detailed (order two) surveys for cropland and less detailed (order three) surveys for rangeland. Figure 2.1-1 shows the differences in degree of detail between second and third order surveys. The SCS maps, descriptions and data serve as the basis for more intensive, site-specific inventories. The published surveys are readily available and free, but the user must go to the SCS field office to obtain unpublished surveys.

The SCS surveys are of uniform quality and are available for most of the coal fields. All the surveys are conducted according to U.S. Department of Agriculture (USDA) standards for the National Cooperative Soil Surveys (NCSS) (USDA 1951, 1975, 1983). These SCS surveys occassionally are criticized for inaccuracies in the mapping, but in our opinion they usually are accurate within the definition of their intended use. The chemical data are not

[illegible]

Key for Identifying Kinds of Soil Survey

Level of data needed	Field procedures	Minimum size delineation Hectares 1/	Typical components of map units	Kinds of map units 2/	Appropriate scales for field mapping and Publication	Kind of soil survey
Very intensive (i.e., experimental plots, individual building sites)	The soils in each delineation are identified by transecting or traversing. Soil boundaries are observed throughout their length. Remotely sensed data is used as an aid in boundary delineation.	1 or less	Phases of soil series; miscellaneous areas	Mostly consociations; some complexes	1:15,840 or larger	1st order
Intensive (i.e., general agriculture, urban planning)	The soils in each delineation are identified by transecting or traversing. Soil boundaries are plotted by observation and interpretation of remotely sensed data. Boundaries are verified at closely spaced intervals.	0.6 to 4	Phases of soil series; miscellaneous areas; few named at a level above the series	Consociations and complexes; some undifferentiated and associated	1:12,000 to 1:31,680	2nd order
Extensive (i.e., rangeland, forest land, community planning)	The soils are identified by transecting representative areas with some additional observations. Boundaries are plotted mostly by interpretation of remotely sensed data and verified with some observations.	1.6 to 256	Phases of soil series and levels above the series; miscellaneous areas	Mostly associations or complexes; some consociations and undifferentiated groups	1:20,000 to 1:250,000	3rd order
Extensive (i.e., regional) planning)	The soils are identified by transecting representative areas to determine soil patterns and composition of map units. Boundaries are plotted by interpretation of remotely sensed data.	40 to 4,000	Phases of levels above the series; miscellaneous areas; phases	Mostly associations; some consociations, complexes, and undifferentiated groups	1:100,000 to 1:1,000,000	4th order
Very extensive (i.e., selections of areas for more intensive study)	The soil patterns and composition of map units are determined by mapping representative areas and applying the information to like areas by interpretation of remotely sensed data. Soils are verified by occasional onsite investigation or by traversing.	1,000 to 4,000	Phases of levels above the series; miscellaneous areas	Associations; some consociations and undifferentiated groups	1:500,000 to 1:1,000,000 or smaller	5th order

1/ This is about the smallest delineation allowable for readable soil maps (see table 2-2). In practice, the minimum size delineations are generally larger than the minimum size shown.

2/ Where applicable, all kinds of map units (consociations, complex, association, undifferentiated) can be used in any order of soil survey, and they are not identified as a particular order of map unit.

Criteria for Identifying
Kinds of Soil Surveys

James P. Walsh & Associates, Inc.

figure 2.1-1

sufficient for the purposes of reclamation planning. They are not intended to be used for reclamation planning and site-specific soil inventories are necessary for this level of detail (section 2.2.1).

The permit applications reviewed typically reference published literature on the use and management of soils in reclamation. The referenced papers are from journals, research organization publications and symposia lectures. The latter are an important source of technical information on surface mine reclamation.

2.1.2 U.S. Geological Survey and Other Sources. Probably the most frequently cited source of geologic information in the case studies reviewed is the U.S. Geological Survey (USGS). The data are in the form of maps, professional papers, bulletins and unpublished open-file reports. There are many different kinds of data at various scales, coverages and ages. In the permitting process, the data are used primarily in the description of the regional geology, stratigraphy and lithology for the baseline studies. The data are readily available from the USGS, Government Printing Office and National Technical Information Service.

The USGS review process is thorough and the quality of the published information is very good.

2.2 Baseline Data Collection and Analytical Techniques

2.2.1 Site-Specific Soil Inventories. All five states in this study have a requirement in either the regulations or guidelines (section 2.7) for a pre-mine site-specific soil inventory. The requirement originally was in the federal regulations but it has been temporarily suspended in part (30 CFR 779.21) according to the most recent regulations (July 1, 1984). In any case, all the permit applications reviewed contained a site-specific soil inventory, more or less according to the standards of the NCSS.

The inventories typically include a soil map, map unit, series and typical pedon descriptions, soil salvage depths and a map legend. The intensity of the inventories varies, but they are fairly detailed (order one or two). Scales range from about 1 inch equals 400 feet (1:4800) to 1 inch equals 800 feet (1:9600) as per state guidelines and some of the state guidelines have specific criteria for the acceptable intensity of mapping (section 2.7). Figures 2.2-1 and 2.2-2 are examples of map units, series and pedon descriptions from a permit application. Figure 2.2-3 is an example of a soil map and legend.

The soils of the sites are sampled for laboratory analysis. One to three profiles are sampled by horizon to a depth of 60 inches or more. The surface horizons are usually sampled in more detail (thinner horizons) than the subsoil. Some state guidelines specify the method of sampling horizons and the number of profiles per soil to be sampled (table 2.7-2).

2.2.2 Soil Analyses. The samples are tested for a suite of agronomic soil properties according to standard agronomic methods, many from the USDA (1969) and the American Society of Agronomy (Page 1982). Even though these are standard agronomic methods, there are some problems (section 4.2.1) The typical analyses are pH, electrical conductivity (EC), sodium adsorption ratio (SAR), saturation percent (Sat%), percent organic matter (OM) and percent sand, silt, and clay. The trace elements boron (B) and selenium (Se) often are determined on salty soils or soils with selenium indicator species, respectively. Nutrient elements (N, P, K) are sometimes determined but they are usually run during topsoil sampling prior to seeding. Figure 2.2-4 is an example of a typical soil laboratory analysis report.

125 - Armolls channery sandy loam, 20 to 35 percent slopes

These are deep, well drained soils on ridges and sideslopes throughout the permit area at elevations of 3200 to 3450 feet. They developed in residuum weathered from fractured Fort Union sandstone. Average annual precipitation ranges from 13 to 19 inches, and the frost-free season is typically 110 to 125 days. Mean annual soil temperature ranges from 42 to 46 degrees F. Slopes are moderately steep to steep.

Typically the surface layer is brown or reddish brown calcareous channery sandy loam about 4 inches thick. The upper part of the substratum is brown or reddish brown calcareous very channery sandy loam about 8 inches thick. The lower part of the substratum is reddish yellow calcareous very channery sandy loam to depths of 60 inches or more. In some profiles the surface layer is leached of calcium carbonates. Coarse fragments comprise 35 to 75 percent of the soil, by volume. The unit is typical of the series.

Permeability is moderately rapid. The available water holding capacity is low. Effective rooting depth is 60 inches or more. Surface runoff is medium and the erosion hazard is slight from wind and water. The unit is in pine woodland with an understory of native range.

Land Capability Classification: VIIs

Topsoil Suitability

This unit is unsuited to use as a source of topsoil because of its high content of coarse fragments.

Prime Farmland Considerations

The Armolls soils falls outside the scope of prime farmland criteria on the basis of its steep slopes, arid moisture regime, and stoniness.

Post-Mining Erosion Hazards

Depending on the size and amount of coarse fragments, this soil may be spread over a wide area, which would essentially eliminate the hazard of erosion from this material. More probably, the material should be buried during grading.

Soil Map Unit Description

Figure 2.2-1

NELAR SERIES

Classification: Entic Haplustoll-coarse-loamy, mixed, mesic family.

Location: Sec. 11 T9S R40E 400 feet north and 150 feet east of W1/4 corner in road cut.

Profile Description: Nelar loam.

A_1 Reddish brown (5yr4/4 when dry) light loam; dark reddish brown (5yr3/4 when moist); moderate fine and very fine granular structure; soft when dry; very friable when moist; nonsticky and nonplastic when wet; few flat fragments.

C_1ca 8-36" Light reddish brown (5yr6/3 when dry) light loam; reddish brown (5yr4/3 when moist); weak coarse prismatic structure; slightly hard when dry; very friable when moist; nonsticky and nonplastic when wet; very strong effervescence with a few threads of lime; few lime coated angular fragments.

C_2 36-80" Reddish brown (5yr5/4 when dry) light loam and fine sandy loam; reddish brown (5yr/4/4 when mosit); massive; soft when dry; very friable when moist; nonsticky and nonplastic when wet; strong effervescence; few lime coated angular fragments.

Range in Characteristics: The texture of control section is loam or sandy loam with less than 12 percent clay and less than 15 percent by volume of angular fragments. Bedrock is typically deeper than 5 feet but can occur above this depth in some profiles. The sandy loam substratum can occur at any depth below 30 inches. In places a very wealky expressed B_2 horizon is present.

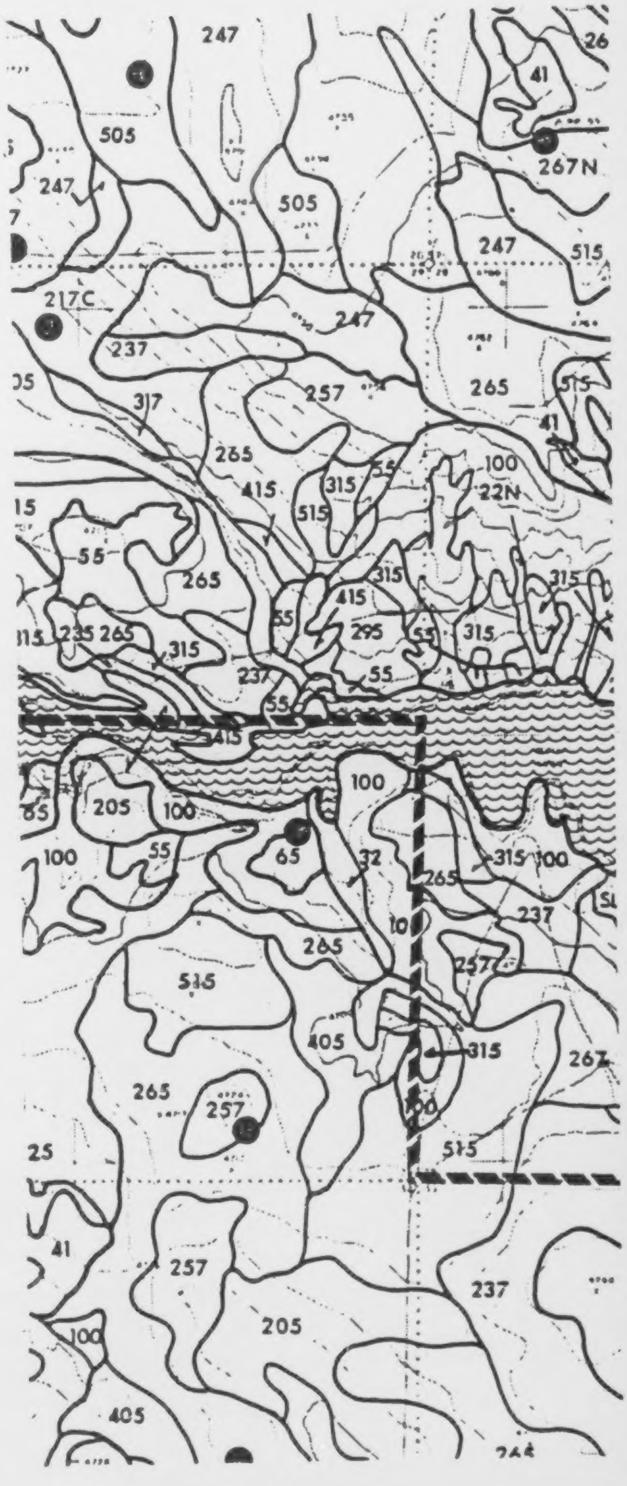
Colors are in hues redder than 7.5yr.

Soil Pedon Description

SOIL CLASSIFICATION LEGEND

22	KIM CLAY LOAM
225	KIMSAL CLAY LOAM
22N	NONKIM CLAY LOAM
32	LIMON CLAY LOAM
41	SAMSIL-LOUVIERS COMPLEX
55	SINGLE-SHAKE COMPLEX
65	THEDALUND LOAM
75	WIBAUX CHANNERY LOAM
82	RENO CLAY LOAM
107	TASSLE FINE SANDY LOAM
107N	LESSAT FINE SANDY LOAM
117N	EMBRY FINE SANDY LOAM
121	NOMIL CLAY
146	DILLINGSON VERY FINE SANDY LOAM
205	CUSHMAN LOAM
217	DONKEY FINE SANDY LOAM
217C	DONKMAN FINE SANDY LOAM
225	FORT COLLINS LOAM
237	MAYSDORF FINE SANDY LOAM
247	OLNEY FINE SANDY LOAM
247N	YENLO FINE SANDY LOAM
257	PUGSLEY FINE SANDY LOAM
257C	PUGMAN FINE SANDY LOAM
265	RENOHILL LOAM
267	RENOHILL FINE SANDY LOAM
267N	RENCALSON FINE SANDY LOAM
295	ULM LOAM
297	ULM FINE SANDY LOAM
307N	VONSON FINE SANDY LOAM
315	THUNDER LOAM
315C	WORFKA LOAM
317	THUNDER FINE SANDY LOAM
325	WORF LOAM
405	ABSTINATE LOAM
405P	ABSTINATE LOAM, PONDED PHASE
407	ABSTINATE FINE SANDY LOAM
415	ABSTED LOAM
415N	ABMAN LOAM
417	ABSTED FINE SANDY LOAM
505	BIDMAN LOAM
505P	BIDMAN LOAM, PONDED PHASE
515	BRIGGSDALE LOAM
100	SHALLOW ENTISOLS
200	PORCELINITE OUTCROPS and VERY SHALLOW SOILS
SL	ROCKLAND, SEDIMENTARY ROCK
CUT	STRUCTURAL CUTS and FILLS
●	SAMPLING LOCATIONS SOIL PROFILE DESCRIPTION LOCATIONS
≋	RESERVOIR

Scale 1" = 1000'


247
26
41
505
267N
247
505
247
515
217C
247
237
257
265
515
317
41
265
415
315
55
515
100
22N
15
55
265
315
415
315
315
235
265
315
295
55
315
237
55
55
415
100
65
205
100
100
55
65
32
265
315
100
237
100
265
257
515
405
315
267
265
257
100
515
25
41
257
237
205
100
405
245

Soil Map Legend and Portion of Soil Map

James P. Walsh & Associates, Inc.

Figure 2.2-3

2.2.3 Geology Description. Most permit applications contain a brief description of regional and site-specific geology and stratigraphy. The typical permit contains a brief description of the geologic basin and overburden formations. The lithologies of the overburden strata are briefly described. The coal bearing units usually are described in more detail and include the number of seams, thickness, coal quality and information on partings and rider seams. In some cases the geologic structures of the area are briefly described if relevant. Figure 2.2-5 is an example of a typical stratigraphic column (taken from the literature) and included in the permit applications to show the relationship of the coal to be mined to the regional stratigraphy. A few sentences on the environment of deposition are often included.

Four of the five states require site-specific geologic mapping of the permit area (section 2.7). In the permit applications reviewed, the geologic maps contained very little detail, typically showing only coal croplines, and some permits did not contain a geologic map.

All five states require some form of geologic cross sections showing the topography, overburden strata, coal seam(s) to be mined and underlying stratum. Most of the cross sections reviewed show the coal seams and topography but almost nothing about the overburden strata. Only one permit (case study E) showed the detailed overburden stratigraphy correlated between drill holes. The same permit application contained a detailed highwall map of the overburden (figure 2.2-6).

2.2.4 Overburden Drilling and Sampling. All five states require premine drilling, sampling and analysis of overburden to provide geologic, lithologic and chemical data in sufficient detail to assist the regulatory authority in determining whether reclamation can be accomplished. The

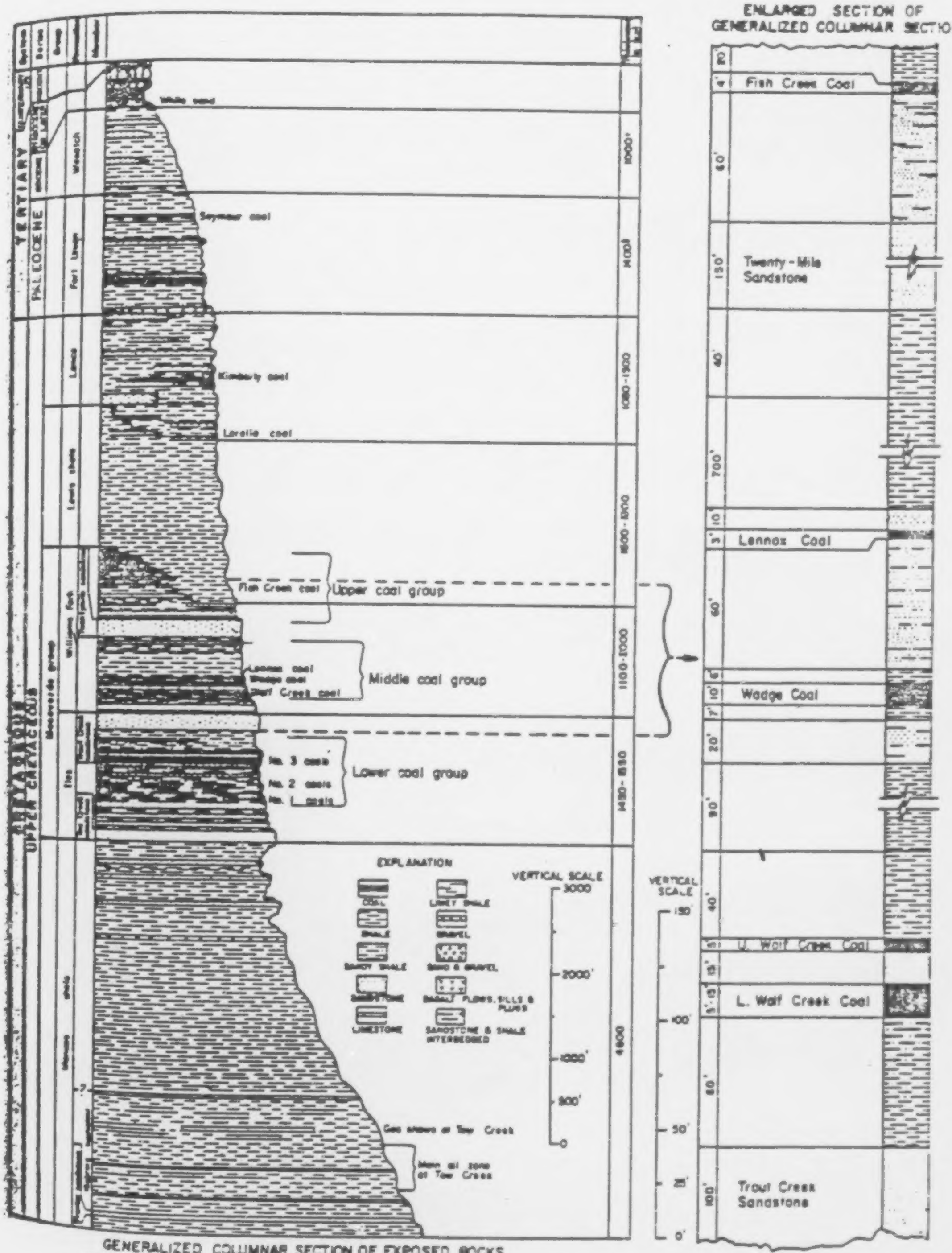
SOIL ANALYSES
FRONT RANGE LAB. INC.
Aug. 1979

Sample	pH (paste)	E.C. mmhos/cm	Sat. %	Ca meq/1	Mg meq/1	Na meq/1	SAR	O.M. %	Sand %	Very Fine Sand %	Silt %	Clay %	Texture
					#1 Yamac Variant (YAB)								
0-4	7.1	0.6	32.2	5.6	2.8	0.7	0.4	3.8	27	26	26	21	SCL
4-8	6.7	0.5	33.1	4.3	2.3	0.5	0.3	2.5	37	30	10	23	SCL
8-12	6.7	0.5	30.0	4.7	2.2	0.5	0.3	1.3	47	27	7	19	SL
12-26	7.0	0.3	23.4	2.4	1.2	0.5	0.4	0.6	66	17	5	12	LS
26-44	7.4	0.5	38.8	3.6	1.8	0.8	0.5	2.9	21	38	14	27	SCL
44-60	7.4	0.5	32.8	3.3	1.8	1.0	0.7	1.8	26	36	15	23	SCL
					#2 Ryan Park (RPB)								
0-5	6.6	0.4	42.5	3.6	1.5	0.3	0.2	3.5	29	43	19	9	SL
5-15	7.0	0.4	33.0	3.8	1.5	0.4	0.2	2.0	30	39	20	11	SL
15-37	7.1	0.5	28.2	3.6	1.5	0.5	0.3	1.1	39	33	15	13	SL
37-42	7.4	0.4	20.4	3.1	1.2	0.7	0.4	0.8	45	33	10	12	SL
42-60	7.8	0.4	27.0	2.5	0.9	1.5	1.0	0.6	50	29	10	11	SL
					#3 Ravalli (RAB)								
0-4	7.6	0.4	38.3	3.9	2.1	6.7	3.9	4.5	26	42	22	10	SL
4-8	7.7	1.1	25.8	3.0	1.4	6.7	4.5	2.9	27	40	20	13	SL
8-21	8.2	4.8	32.5	3.8	8.7	48.4	19.4	2.7	27	36	16	21	SCL
21-42	8.1	12.1	35.5	7.9	67.0	125.0	20.4	1.8	23	39	18	20	SCL
32-48	7.9	12.3	30.4	22.3	119.7	112.0	13.3	1.2	34	36	14	16	SL
48-60	8.0	0.5	37.8	11.5	3.8	69.2	10.6	1.6	28	38	15	21	SCL
					#4 Santanka (SAC)								
0-6	7.3	0.8	27.3	5.8	3.4	0.9	0.4	3.3	48	27	14	11	SL
6-19	6.7	0.5	36.9	3.0	4.1	0.9	0.5	1.5	43	29	10	18	SL
19-35	7.8	0.5	29.0	2.1	2.7	1.2	0.8	0.8	29	36	17	18	SL
35-40	8.0	0.5	35.9	2.1	3.8	1.1	0.7	0.7	33	36	15	16	SL

Typical Soil Analysis Report

James P. Walsh & Associates, Inc.

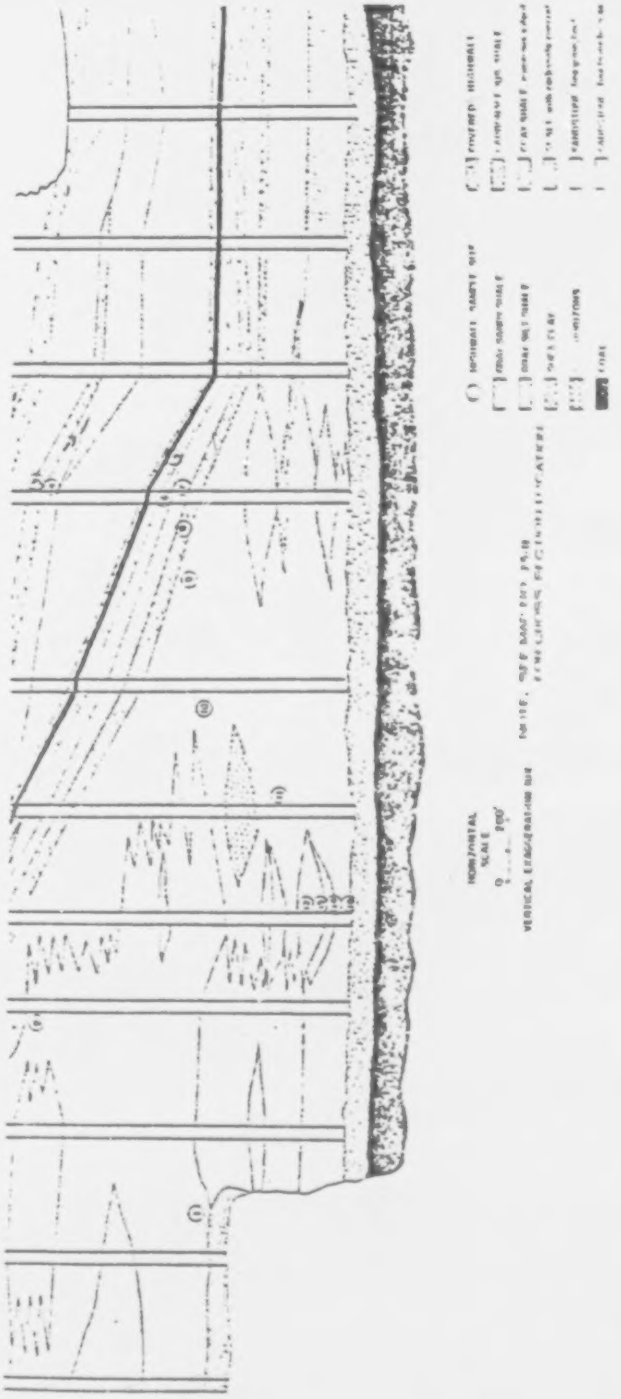
Figure 2.2-4


System
Series
Group
Formation
Member
TERTIARY
PALEOCENE
UPPER CRETACEOUS
Wasatch
Fort Union
Lance
Lewis shale
Williams Fork
Mesaverde group
Iles
Mancos shale
White sand
Seymour coal
Kimberly coal
Lorella coal
Fish Creek coal
Upper coal group
Lennox coal
Wadge coal
Wolf Creek coal
Middle coal group
No. 3 coals
No. 2 coals
No. 1 coals
Lower coal group
Gas shows at Tow Creek
Main oil zone at Tow Creek
1000'
1100'
1080-1300
1600-1200
1100-1000
1430-1530
4800
EXPLANATION
COAL
SHALE
SANDY SHALE
SANDSTONE
LIMESTONE
LIMEY SHALE
GRAVEL
SAND & GRAVEL
BASALT FLOWS, SILLS & PLUGS
SANDSTONE & SHALE INTERBEDDED
VERTICAL SCALE
3000
2000'
1000'
500'
0
ENLARGED SECTION OF GENERALIZED COLUMNAR SECTION
Fish Creek Coal
Twenty-Mile Sandstone
Lennox Coal
Wadge Coal
U. Wolf Creek Coal
L. Wolf Creek Coal
Trout Creek Sandstone
20
4'
60'
150'
40
700'
10
3'
60
6'
10'
7'
20'
90'
40'
15'
5'-15'
60'
100'
VERTICAL SCALE
150'
100'
50'
25'
0'

GENERALIZED COLUMNAR SECTION OF EXPOSED ROCKS IN PARTS OF ROUTT AND MOFFAT COUNTIES, COLORADO

Stratigraphic Column

James P. Walsh & Associates, Inc. Figure 2.2-5



Highwall Map and Sampling Locations

James P. Walsh & Associates, Inc.

figure 2.2-6

drilling, sampling and analysis is also required to identify acid- or toxic-forming or alkaline producing materials (30 CFR 780.22).

The intensity of required sampling varies among the states, from one hole per section (640 acres) as a minimum in Colorado up to one hole per 40 acres in North Dakota and Montana. Samples are collected as cuttings from rotary drilling or as continuous cores. The rotary drill holes can be part of the coal exploration drilling, but coring the overburden is part of a normal exploration program. The lithology of either the cuttings or core are described in drillers' logs or in detail by a geologist. In some cases geophysical logs are submitted to supplement the lithologic descriptions. Figure 2.2-7 shows a typical overburden lithology log. The cuttings usually are collected at 5-foot intervals. The cores are sampled at major lithologic changes or at about 10-foot intervals.

Rotary drilling is often used for sample collection, but it is a somewhat crude method. There is mixing of the sample as it rises in the hole, so the interval from which it comes is not precise and 5-foot intervals often will include more than one lithology. There also is a problem of contamination from the drilling fluids. The possibility of contamination may be less for coring and there is no mixing, but it is much more expensive.

2.2.5 Overburden Sample Analysis. The overburden samples are tested for a suite of parameters selected to be representative of the effects on soils, vegetation and water quality. Some of these tests are the same as the soil tests, but the sample preparation is different; cuttings and core samples must be ground prior to testing. The parameters tested typically are pH, salinity, sodium adsorption ratio and/or exchangeable sodium percent, texture, saturation percent and in some cases acid-base potential (ABP) and trace metals. In New Mexico, a suite of 23 trace metals has been required as part

MINE NAME: ____________________ BED: ______ HOLE NO. ________

COUNTY: ________ STATE: ________ SEC. ____ TWP. _____ RG. ________

DRILLER: ______________ DATE: ______________ EL. ________

PAGE ____ of ____

TOTAL Ft. & 10ths			THICKNESS Ft. & 10ths		SUB-SAMPLE	COMPOSITE SAMPLE
0	-	Siltstone, light gray, sandy	10	0		
10	0	Sandstone, very fine grained, yellow, silty,	5	6		
		<10% carbonaceous				
15	6	Shale, light gray-yellow, sandy, limonite	7	1		
		stained, <10% carbonaceous				
22	7	Sandstone, very fine-fine grained, buff,	2	9		
		slightly calcareous				
25	6	Shale, buff-gray, limn. stained, gypsum,	3	9		
		<10% carbonaceous				
29	5	Sandstone, very fine-fine grained tan		2		
29	7	Shale, gray, <10% carbonaceous, limonite	4	9		
		stained				
34	6	Sandstone, very fine grained, tan, slightly	5	6		
		calcareous, shaley				
40	2	Limestone, light gray, <10% carbonaceous	1	2		
41	4	Sandstone, very fine grained, tan, calcareous,	4	4		
		<10% carbonaceous, shaley				
45	8	Shale, gray, sandy, >10% carbonaceous	2	7		
48	5	Carbonaceous shale, w/coal, pyritic		2		
48	7	Shale, gray, sandy, <10% carbonaceous	11	3		
60	0	Sandstone, very fine grained, gray, slightly	21	8		
		calcareous, shaley, <10% carbonaceous				
81	8	Shale, gray, >10% carbonaceous	1	8		
83	6	Sandstone, very fine grained, light gray,	13	3		
		shaley, calcareous, <10% carbonaceous				
96	9	Shale, gray, sandy, <10% carbonaceous	29	6		
126	5	Sandstone, very fine-fine grained, light gray,	4	0		
		<10% carbonaceous, w/shale stringers				
130	5	Shale, gray, sandy	2	0		
132	5	Sandstone, very fine-fine grained, salt &	1	0		
		pepper, shaley, <10% carbonaceous				
133	5	Shale, gray, sandy, <10% carbonaceous	14	2		
147	7	Sandstone, very fine-med. grained, salt &	5	4		
		pepper, <10% carbonaceous, shaley				
153	1	Shale, gray, <10% carbonaceous	1	6		
154	7	Coal, pyritic	1	9		
156	6	Coal	4	0		
160	6	Bone coal		3		
160	9	Coal, pyritic	2	1		
163	0	Carbonaceous shale, w/coal strands		2		
163	2	Coal	1	1		
164	3	Carbonaceous shale		2		
164	5	Coal, pyritic	1	1		
165	6	Carbonaceous shale		1		
165	7	Coal, pyritic	13	7		
179	4	Carbonaceous shale, w/coal, pyritic		2		
179	6	Coal		9		
180	5	Carbonaceous shale		8		

Geologic Log

James P. Walsh & Associates, Inc.

Figure 2.2-7

of the regulations, but the requirement is now being routinely waived; in North Dakota testing for trace metals is not required (section 2.7).

2.3 Reclamation Planning and Techniques

Reclamation planning and soil and overburden handling are site-specific processes and each case study reviewed had its own unique problems to solve. Nevertheless, certain approaches to the problems have become somewhat standard in the five state study area.

2.3.1 Criteria for Soil Use. A somewhat simplistic approach to the use of the soil resource is the standard practice. Soil samples representative of soil horizons are rated as suitable or unsuitable according to some chemical or physical criteria. For any given series, the depth to the top of the shallowest unsuitable horizon is the recommended salvage depth for that soil. All suitable materials are salvaged for use and unsuitable materials are spoiled with the overburden.

The criteria for soil use are much the same among the five states, but the levels considered unsuitable vary slightly among the regions due to ecologic differences, reclamation objectives and professional judgements. The criteria used typically are pH, salinity, sodium adsorption ratio, boron and selenium. If none of the above criteria are limiting, depth to bedrock is the usual limiting factor, although at some mines, soils are not salvaged below 5 feet even if entirely suitable chemically (section 4.2.1). The system is somewhat more refined in North Dakota, as that state has criteria for a first and second lift. In practice, lift one is the dark colored surface horizon (in many cases the mollic epipedon) and the subsoil is the material that meets lift two criteria. Table 2.3-1 compares the cut-off value for unsuitable materials for soil use among four of the five states (Colorado has no

Table 2.3-1

TOPSOIL UNSUITABILITY CRITERIA BY STATE

parameter	Montana (DSL 1983) (lift 2 only)	New Mexico (MMD 1984)	North Dakota (NDPSC, 1983) (lift 2 only)	Wyoming (WDEQ 1984)
pH acid	<5.5	<6.0	none given	<5.0
pH alkaline	>8.5	>9.0	none given	>9.0
EC (mmhos/cm)	>4.0-8.0	>16.0	>4.0	>12.0
texture	excessively clayey, silty or sandy	none given	none given	none given
$CaCO_3$%	none given	none given	none given	none given
Sat %	<25% >85%	none given	none given	none given
SAR	>11.0 >14.0 depending on texture	12.0 >15.0 >20.0 depending on texture	>10.0	15.0 >12.0 depending on texture
ESP	>15.0 >18.0 depending on texture	none given	none given	none given
B	>5.0 ppm	>5.0 ppm	none given	>5.0 ppm
Se	>0.1 ppm	>0.5 ppm	none given	>0.1 ppm
coarse fragments (% volume)	>35%	none given	none given	>35%

published guidelines).

Workers at case study mine M used an innovative technique to evaluate soil suitability. Several soil pedons were described, sampled and analyzed for the standard set of parameters. A soil potential rating for topsoil was developed from the data and pedon descriptions (figure 2.3-1). A numerical rating was assigned to several chemical parameters and a rating was given for the whole soil and the limiting horizon and summed. In this method the relationship between sodium adsorption ratio and clay was expressed as sodium adsorption ratio times clay percent divided by ten. This system represents an attempt to weigh several chemical and physical parameters rather than use unsuitability criteria. The system might be refined to optimize use of the soil resources at a site.

The site-specific soil inventories (section 2.2.1) are used to calculate soil volumes for reclamation planning. Available soil volume is calculated in the following manner. The area of each soil map unit to be disturbed is measured from an overlay of the mine plan on the soil map. The composition of the map units should be known from the soil inventory (i.e., the percent of different soil phases that make up the map unit). The salvage depth is determined from the chemical analysis and the suitability criteria. Volume available (in acre-feet) equals the area of the map unit (in acres) times percent of each component times salvage depth (in feet) summed over all the components and all affected map units. The volume of available soil divided by the area to be redressed gives the average thickness of soil redressing. Figure 2.3-2 is a topsoil volume table that illustrates the calculation as per Wyoming Department of Environmental Quality (WDEQ) Guideline No. 1 (1984).

A few mines have their soil inventory and mine plan data digitized so that they can evaluate available topsoil volumes on a continuous basis as

Table 3. Numerical ratings of physical and chemical properties of soils to determine potential rating for use as "Topsoil" in reclamation.

Soil Parameters	Pedons		
	1-Muff	2-Youngston Variant	3-Huerfano
	Index*		
Texture:			
Average	--	10	10
Limiting Layer	10	10	20
% Clay above 27	--	--	3
SAR x Clay/10:			
Average	61	34	135
Limiting Layer	72	50	266
EC:			
Average	10	5	10
Limiting Layer	10	10	10
Depth	30	--	60
CaCO3:			
Average	--	--	--
Limiting Layer	--	--	--
Coarse Fragments:			
Average	--	--	--
Limiting Layer	--	--	--
Boron	--	--	--
Total Index Rating	193	119	514

*Soils with lowest total are rated best for topsoil. A detailed description of Pedons 1 through 3 is in the Appendix.

Table 4. Suitability of soil as a source of topsoil.

Soil Parameter	Soil Rating (Index *)		
	Good	Fair	Poor
Texture	Sl, SiL, L (0)	SC, CL, SCL, SiCL (10)	S, LS, C SiC (20)
Water at Saturation (%)	>25		<25
pH	<8.4	8.4-8.9	>8.9
Sodium Absorption Ratio (SAR)	<6	6-15	<15
Electrical Conductivity (Ec)	<4 (0)	4-8 (5)	>8 (10)
Coarse Fragments (%)	<15 (0)	15-35 (10)	>35 (20)
CaCO3 (%)	<15 (0)	15-30 (10)	>30 (20)
Depth (in)	>40 (0)	20-40 (30)	<20 (60)
Boron (mg/l)			>4 (20)

* The numbers in parentheses are the index values used to develop table 3.

Weighted Topsoil Quality Evaluation

James P. Walsh & Associates, Inc.

figure 2.3-

Table II-1
Topsoil Volume Summary

Mapping Unit Symbol & Name	Composition of Mining Area Acres	%	Composition of Mapping Unit in % (Should include (inclusions)	Depth of Topsoil (inches)	Total Volume of Topsoil (A-ft)	Average Salvage Volume of Topsoil (A-ft)	Salvage Depth of Topsoil (inches)	Limitations [1]
1A Haverson loam	25.6	4.0	100	60+	128.0	50.7	28.0	SAR 15 at 28 in.
2B Bidman loam	76.8	12.0	90	50	345.0	345.0	50.0	
(Briggsdale sandy loam)			10	29	18.6	18.6	29.0	
44C Tassel-Shingle	44.8	7.0						
Rock outcrop complex			50	18	33.6	33.6	18.0	
Tassel								
Shingle			25	8	7.5	7.5	8.0	
Rock outcrop			25	0	0.0	0.0	0.0	
5A Stoneham loam	96.0	15.0	90	60	432.0	432.0	60.0	
(Cushman)			10	24	19.2	19.2	24.0	
7B Briggsdale sandy loam	140.8	22.0	95	29	323.2	323.2	29.0	
(Shingle)			5	12	7.0	7.0	12.0	
9A Ft. Collins-Ulm	70.4	11.0						
Association			50	60	176.0	176.0	60.0	
Ft. Collins								
Ulm			45	60	158.4	58.4	60.0	
(Shingle)			5	12	3.5	3.5	12.0	
6B Thedalund	108.8	17.0	100	24	217.6	217.6	24.0	
7B Cushman	76.8	12.0	100	24	153.6	153.6	24.0	
TOTAL	640.0	100.0			2023.3	1951.9		

( ) indicates inclusion

Average depth of replacement

$$\frac{1951.9 \text{ A-ft}}{640 \text{ A}} = 3.0$$

---

[1] Where topsoil salvage depth is different from the depth of topsoil, the limiting factor should be defined.

Topsoil Volume Summary

James P. Walsh & Associates, Inc.

figure 2.3-2

necessary, or as more information on topsoil depth becomes available and the mine plans are revised.

2.3.2 Overburden Characterization and Delineation of Deleterious Strata. After the applicants have drilled, described, sampled and analyzed the overburden (section 2.2.5), the geochemistry of the strata is evaluated. The primary objective is to demonstrate the reclaimability of the material; a secondary objective is to determine if any of the strata have particularly deleterious (or favorable) characteristics that require special handling and the volumes of such material. Overburden characterization is conducted in a manner similar to the characterization of suitable and unsuitable soil horizons. The regulatory authorities in several states have developed criteria for overburden chemical suitability (table 2.3-2) but they are the subject of debate (section 4.2.3). These criteria have been undergoing revision since the passage of the first state laws in the early 1970's. At the present time some states have criteria established for pH, salinity, sodium adsorption ratio, exchangeable sodium percent, acid-base potential, boron, texture, molybdenum, organic carbon and selenium. These criteria are dependent on certain prescribed analytical techniques. The criteria often are referred to as "suspect levels"; strata with chemical values above suspect levels are considered unsuitable for use in the reconstructed root zones (and/or in reconstructed aquifers) and in some cases are considered "toxic" according to SMCRA regulations and are handled accordingly. Table 2.3-2 shows the current criteria for overburden unsuitability for three of the five states (both Colorado and North Dakota have no published guidelines). For many trace metals, suspect levels are not well established.

The overburden at a site can be all suitable or unsuitable, or more typically, a mixture of both. In one case study, all of the overburden

Table 2.3-2

OVERBURDEN UNSUITABILITY CRITERIA BY STATE

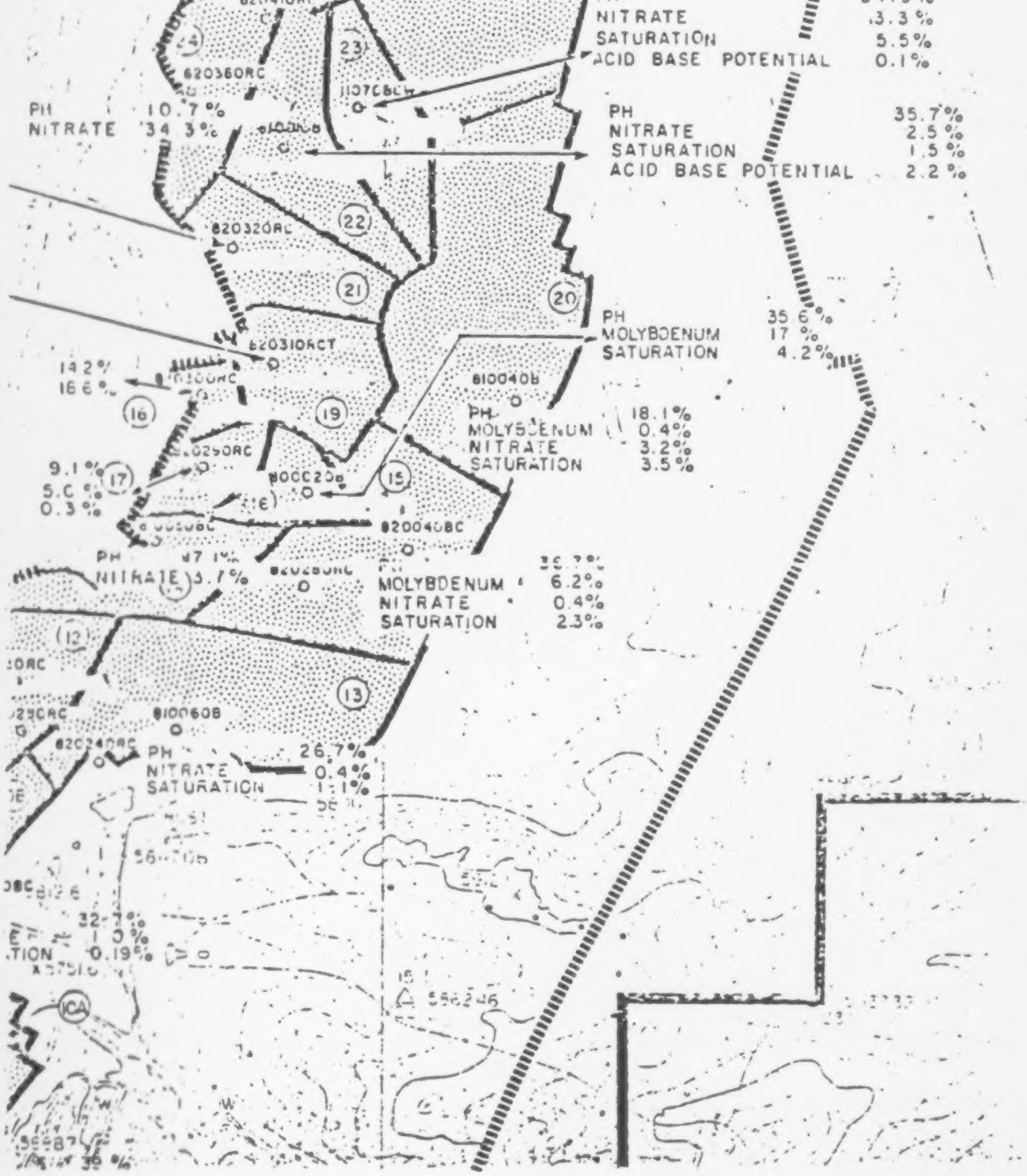
parameter	Montana (DSL 1983)	New Mexico (MMD 1984)	Wyoming (WDEQ 1984)
pH acid	<5.5	<6.0	<5.0
pH alkaline	>8.5	>9.0	>9.0
EC (mmhos/cm)	>4.0-8.0	>16.0	>12.0
texture	excessively clayey, silty or sandy	none given	none given
Sat %	<25% >85%	none given	none given
SAR	none given	>12.0 >15.0 >20.0 depending on texture	>12.0 >15.0 depending on texture
ESP	>15.0 >18.0 depending on texture	none given	none given
B	>5.0 ppm	>5.0 ppm	>5.0 ppm
Se	>0.1 ppm	>0.5 ppm	none given
ABP	none given	0 tons $CaCO_3$ equivalent/ 1000 tons	<-5 tons $CaCO_3$ equivalent/ 1000 tons
Mo	>0.5 - 1.0 ppm	none given	none given
Organic Carbon	none given	none given	>10%

was found to be benign and reclaimability was not an issue. In several case studies, essentially all of the overburden was found to be deleterious and the applicants were required to find sufficient thickness of soil cover to show reclaimablility to the satisfaction of the regulatory authority (section 5.3). In the typical situation, where some of the overburden is deleterious and some is benign, the applicants are required to demonstrate that the deleterious overburden will not occur in the reconstructed soil root zone. This is accomplished by some combination of special handling of deleterious materials, providing 4 feet or more of benign cover and conducting recontoured spoil sampling programs (section 4.3.2).

Where the overburden is a mixture of suitable and unsuitable materials, the applicants must delineate or define the unsuitable strata in some manner so that the regulatory authority can assess reclaimability and the need for special handling. A number of different approaches were used in the case studies reviewed. One approach is to describe the deleterious zones in the overburden; for example case study G described a stratigraphic zone high in nitrate generally within 50 feet of the ground surface (section 3.7.3). Another approach is to describe the deleterious strata based on lithology; case study G also described strata of high acid-base potential in an orange to beige, coarse-grained unconsolidated sandstone (section 3.7.3). One case study characterized the geochemistry of the different mine benches (section 3.6.2), and another (section 3.10.2) presented the data in a statistical breakdown of means, standard deviations and ranges for each chemical parameter (but this approach does not address the question of correlating geochemical values to particular materials).

Another approach (often used for dragline operations) is to map deleterious areas based on the drill hole data. Drill hole locations are plotted and areas of influence drawn around each hole. The areas of influence are considered unsuitable if a certain percentage (by thickness) of the hole (or a bench) is unsuitable. It is a working assumption that if the unsuitable overburden is less than 15 percent for dragline operations, or less than 20 percent (of a mining bench) for truck and shovel operations, it will be mixed adequately and therefore will not be measurable (or a problem) on the surface of the recontoured spoil. The assumption is based on one quantitative study at one location (Dollhopf *et al*. 1981) and field experience, and is at best a rule of thumb. The position of the deleterious material in the overburden is also important; in a dragline operation, material at the bottom of the dragline bench is likely to end up near the surface of the recontoured spoil. Figure 2.3-3 is an example of a map of unsuitable areas based on drill hole areas of influence; the unsuitable parameters and their percentages are also shown.

2.3.3 *Overburden Handling*. At mines with deleterious overburden strata the regulatory authority may require additional drilling, sampling and analysis of overburden during operations, special handling of deleterious strata or recontoured spoil monitoring. If drilling and sampling is required it is usually conducted on a progressive basis prior to stripping and may utilize coal quality drill holes, overburden blast holes and highwall sampling. It is important to delineate deleterious strata even in dragline operations that will not special handle, in order to establish areas on the recontoured surface where spoil may have deleterious qualities. In situations where all of the overburden is benign (case study A) or all unsuitable (case studies A, B, D and L) the regulatory authorities do not usually require additional drilling, special handling or monitoring.


POTENTIAL 0.2% 0.6%
PH 22.5%
NITRATE 4.05%
SATURATION 0.05%
ACID BASE POTENTIAL 0.3%
PH 34.9%
NITRATE 3.3%
SATURATION 5.5%
ACID BASE POTENTIAL 0.1%
PH 10.7%
NITRATE 34.3%
PH 35.7%
NITRATE 2.5%
SATURATION 1.5%
ACID BASE POTENTIAL 2.2%
PH 35.6%
MOLYBDENUM 17%
SATURATION 4.2%
14.2%
18.6%
PH 18.1%
MOLYBDENUM 0.4%
NITRATE 3.2%
SATURATION 3.5%
9.1%
5.0%
0.3%
PH 37.1%
NITRATE 3.7%
MOLYBDENUM 6.2%
NITRATE 0.4%
SATURATION 2.3%
PH 26.7%
NITRATE 0.4%
SATURATION 1.1%
32.7%
1.0%
0.19%
820410RC
820360RC
1107CBCW
820320RC
820310RCT
810040B
820290RC
800C20B
820040BC
810060B
820240RC
20
21
22
23
24
19
16
17
15
13
12
1CA
586246

Map of deleterious overburden areas showing unsuitable parameters

James P. Walsh & Associates, Inc.

figure 2.3-3

In North Dakota, it may not be important to delineate deleterious strata as that state requires up to 5 feet (a minimum of 4) of soil material to be placed over the recontoured spoil for all mines, whether the spoil is deleterious or not. This requirement originally was based on the assumption that most of the overburden in the state was clayey and sodic (now known not to be the case). With 5 feet of cover, chemical and physical characteristics of the spoil are less important than at mines where only 1.5 to 2 feet of soil may be redressed.

If it is determined that deleterious strata are a potential problem for revegetation of the recontoured surface (or to post-mining groundwater quality), a program of special overburden handling may be required. Special overburden handling cannot be accomplished very effectively for dragline operations. They are limited essentially to a modified dragline swing which increases the likelihood of undesirable strata being spoiled on the bottom of the spoil piles and being below the recontoured surface after grading. In case study C, a dragline operation was required to double handle spoil at great expense in order to prevent a possibly deleterious interburden from ending up on the recontoured surface.

Truck and shovel operations have a much greater ability than dragline operations to special handle deleterious (or favorable) strata. In addition, the top bench usually is spoiled at the top of the spoil and it is more likely to be benign (in chemical equilibrium with a surface environment) than deeper benches.

The problems of overburden handling can become increasingly complex. Some parameters are deleterious to revegetation of the recontoured surface (i.e., sodium adsorption ratio), others present a groundwater quality problem (nitrate), and some others are both (ie, selenium). This paper addresses problems of the reconstruction of the reclaimed surface for the purposes of revegetation and reclamation, but problems associated with the reconstruction of post-mining groundwater systems are addressed in a companion OTA report (Western Water Consultants, Inc. 1985).

2.3.4 The Recontoured Surface. All five states require the establishment of the approximate original contour (AOC) as per federal regulations (section 2.7) unless specifically exempted due to excess or thin overburden. In the baseline studies, the achievement of approximate original contour often is demonstrated with the comparison of pre-mining and post-mining slope classes. Histograms comparing the frequency of occurrence of various slope classes between pre-mining and post-mining conditions are sometimes used to show that slopes are neither steeper nor excessively flatter after mining. The achievement of approximate original contour is also demonstrated by the proposed post-mining topographic map.

The slope of the recontoured surface will have critical effects on the post-mining vegetation, land use and stability, but the construction of the slopes must minimize recontouring costs, by far the most expensive reclamation activity. The design of the recontoured surface must produce a stable post-mining landscape that is not subject to excessive erosion or deposition, is compatible with the post-mining land use, and accomplishes several other required objectives. For example, in North Dakota, landform is very important in post-mining vegetation productivity because of its effect on available moisture (Halvorsen, Zimmerman and Melsted 1981) and in design of the post-mining surface for case study B, the regulatory authority required the operator to locate a small field of prime farmland on a concave landscape position to maximize water run-on and snow accumulation.

Recontoured spoil sampling programs are being conducted at several case study mines (mostly in Wyoming) to verify the quality of spoil material on the recontoured surface prior to topsoiling. For dragline operations, this probably is the most practical method to avoid having unsuitable materials in the root zone. Spoils are sampled in a grid pattern with a spacing of about 400 feet. Samples are collected in 2-foot intervals to a depth of 4 feet (two 4-foot intervals in Montana) and analyzed for the parameters known to be of concern from the baseline studies. If a sample is found to be unsuitable, additional samples are collected around it on a closer grid (or at four compass points 100 feet away, or in a triangle, etc.) until the unsuitable area has been delineated. Another method that has been used is to take about ten sample locations from a 5 acre parcel, composite the 0 to 2-foot and 2 to 4-foot intervals and test two composite samples to be representative of the 5 acre parcel (but this method was not acceptable to the regulatory authority).

Once deleterious material has been identified on the recontoured spoil, it must be covered, disposed of, or treated. The simplest solution is to cover it with an appropriate thickness (4 feet or more) of suitable spoil from an adjacent area. If this is not practical, the deleterious material may have to be rehandled and buried in the pit or spoil piles. The worst case would occur where so much of the spoil is unsuitable that there is insufficient material to provide the required amount of suitable material on the surface. In this case, treatment may be required by the regulations, but chemical treatment is expensive and may not be a very effective solution (Boon, undated).

The recontoured spoil surface must be prepared for topsoiling. The graded spoil is typically ripped with a chisel plow to alleviate compaction, prevent a barrier from forming at the interface of the spoil and soil, and prevent the soil from slipping on the surface of the spoil.

Subsidence of recontoured surfaces has occurred in North Dakota, Montana, Wyoming and Colorado. Enough subsidence has occurred at some mines in the Northern Great Plains to cause cracking differential displacement, piping and some potholes (Groenwald and Rehm 1980). In North Dakota this problem has been attributed to recontouring frozen spoil containing large amounts of snow. At one mine in Montana, an area parallel to dragline spoils subsided and produced a 1-foot high scarp, a few cracks several hundred feet long, and a depression about 4 feet deep, 50 feet wide and 200 feet long. At another mine the water in a small surface drainage on a recontoured surface disappeared into a subsidence crack at the positon of an endwall. The one case study (mine D) with subsidence data available in annual reports shows less than a foot of subsidence five years after recontouring. Most subsidence should occur within a few years after recontouring; the environmental manager at one case study mine suggested that final grading and topsoiling might have to be postponed for several years to allow for settling. At least one landowner interviewed for this study is concerned that differential settling and cracking may make some lands unsuitable for livestock grazing after mining. This author's impression during the course of this study was that neither industry or the regulatory authority considers subsidence to be an important problem.

2.3.5 Soil Handling. Salvaging and redressing soil involves delineating the areas and depths to be stripped, stripping in either one or two lifts, stockpiling and redressing, or applying the soil directly after salvage (referred to as direct-haul). Redressing is either in uniform or non-uniform thickness. After redressing, the soils are prepared for seeding and treatment.

The pre-mine soil inventories are sufficiently accurate for the purposes of reclamation planning, but actual salvage requires more intensive determinations of salvage depth and delineation of soil bodies to be stripped, and most mines have developed systems to assure that the right amount of soil is salvaged from the appropriate areas. In most cases, a qualified person using the baseline soil inventory map as a guide, places cut stakes on 200-foot centers based on visual observations and/or testing of auger hole samples. In some cases a staking program may not be necessary; at case study C the only limiting soil factor is sandstone bedrock below the subsoil, and soils are salvaged to that depth without a staking program. Pillars of undisturbed soils can be left standing in the salvage areas to show that all suitable soil has been salvaged. Soil volume accounting (a type of soil budget showing volumes available) is sometimes used by the regulatory authorities to assure that adequate volumes of soil materials are being salvaged (section 4.3.1).

Soils usually are salvaged by scrapers, but deep soils are sometimes salvaged using truck and shovel equipment, and very small mines use whatever equipment is available.

Soils are handled in one or two lifts. Two lifts require that surface materials are kept segregated from subsurface materials and redressed with surface soils over subsoils; the organic rich and biologically active materials are put on the surface of the reconstructed soil. Montana, North Dakota, and sometimes Colorado, require two lifts. One operator in the Wyoming case studies (case study I) is using two lifts by preference.

In direct-haul handling, soils are salvaged and redressed in a single operation. Most operators in this study are stockpiling and rehandling most of their soils, but many use direct-haul on a limited basis and a few use it almost exclusively. According to one of these operators, rehandle is expensive, and the haul distance with direct-haul can be shorter. Direct-haul may be less expensive than stockpiling if it is incorporated into the initial mine plan.

Two lift direct-haul may be the best method of soil handling, especially for the re-establishment of rangeland diversity (Western Resource Development Corp. and Bunin 1985). This method minimizes handling impacts and puts the biologically active layer back on top. There is very little research on the two lift direct-haul topsoiling method, but research on one lift direct-haul indicates that it is very effective (relative to stockpiled topsoil) in providing for species diversity (Jastrow _et al_. in press).

A few mines in the study are using two lift direct-haul topsoiling. A strip of topsoil is salvaged and temporarily stockpiled. Subsoil from that strip is picked up and applied to the recontoured spoil in the reclamation area. Topsoil from the next strip in the salvage area is then picked up and applied over the redressed subsoil. This continues to the end of the salvage area, at which time the temporary stockpile is picked up and redressed over the last band of redressed subsoil.

Federal regulations require topsoil to be redressed in a uniform thickness consistent with the post-mining land use. Montana has a provision in their rules for special reconstruction of soils using non-uniform depths, but the other states routinely require uniform thickness. Some case study mines are redressing a uniform thickness, but several are not.

There are numerous methods of preparing the redressed topsoil and preventing erosion. These include contour furrowing, ripping on the contour, surface pitting, discing, terracing, and mulching. The redressed surface soil may be tested for fertilizer requirements prior to seeding. Irrigation has been used at a few case study mines.

2.3.6 _Special Soil Reconstruction_. The re-establishment of ponderosa pine is a sophisticated mine reclamation problem in portions of the eastern Powder River Basin and several mines (including case study C) are working on the problem. The ponderosa pine only occur on scoria knobs and resistant sandstone ridges in that environment and the mining process will remove the substrate condition on which they depend. The present plan is to re-establish ponderosa in a thick layer of scoria or very gravelly soil over a compacted layer of spoil. The compacted spoil is a barrier to soil moisture movement and creates a moist zone within reach of the roots, and the coarse material provides for rapid infiltration.

At case study A, another special soil reconstruction technique is being used to recreate wetlands in prairie potholes for wildlife habitat. The prairie potholes were formed when blocks of ice calved off the receeding glacial ice sheets and were then buried in outwash sediment. The ice melted, and depressions were formed which subsequently became clogged with clayey sediments. These slowly permeable, clayey sediments provide the substrate conditions necessary for the pothole wetlands and are being specially handled and replaced into man-made depressions on the reclaimed surface to reconstruct this important habitat type.

2.3.7 Supplemental Soil Materials. The regulations of all five states allow the use of supplemental overburden material in addition to, or in place of existing soils, where the supplemental material are as good or better (section 2.7). In this study area, overburden is almost never better than the existing soil. However, case study mine M has virtually no topsoil and the surficial materials are highly sodic and clayey shales, so a sandstone unit in the overburden is being used as an alternative to topsoil. The sandstone is salvaged from the pit, stockpiled separately from the overburden, and redressed like soil.

2.4 Methods for Predicting Reclamation Success

SMCRA requires that "...the permit application affirmatively demonstrates and the regulatory authority finds on the basis of information set forth in the application or from information otherwise available...that reclamation as required by this act and the state or federal program can be accomplished under the reclamation plan contained in the permit application" (Public Law 95-87, Sec. 510). This has become known as the "findings of reclaimability". The regulatory process involved in this decision is described below.

2.4.1 Compliance. The principal method by which the regulatory authority approves a permit application is to determine whether it complies with all of the state regulations. It is to some extent assumed that if a plan complies with all of the regulations, reclamation will be achieved.

2.4.2 Spoil Quality and Redressed Soil Thickness. There are many aspects to reclamation, but in terms of soil and overburden, the principal model used to predict reclamation success is an informal model of spoil quality and redressed soil thickness. Much research has been conducted to show the thickness of soil required over coal mine spoils. The research has been conducted in all five states, over various kinds of spoil, using different revegetation species, and with different criteria for evaluating the revegetation results. Some of the major factors that affect the optimum soil thickness for revegetation of spoils are vegetation type, soil quality, spoil quality, landscape position, and average annual precipitation.

Table 2.4-1 summarizes some of the published research on topsoil thickness requirements in the region. As seen on table 2.4-1, the optimum depth of redressed soil increases as spoil quality decreases. A very thin (6 inch) soil layer may be effective over benign spoils, whereas a very thick layer (greater than 60 inches) may be required over the most deleterious spoils.

Table 2.4-1
SUMMARY OF SOME TOPSOIL DEPTH RESEARCH

Overburden Quality	Topsoil Quality	Land Use or vegetation	Region	Optimal Depth	Comments	Reference
no adverse properties, similar to soil	non-saline, non-sodic, loamy	cool season grasses	eastern Powder River Basin	no soil required	it appears that in some areas of the Northen Great Plains spoil is equal to soil in its ability to support plant production	Barth and Martin 1982
---	---	wheat	coal strip MT	greater than 4 in	4-8 in adequate	Sindelar, Hodder and Majerus, 1973
slightly saline	---	wheat grain	ND	6 in	no higher yields on thicker topsoils	Bauer et al. 1978
good	---	row crops	---	6 in minimum	may not be a significant in later years	Jansen, Dancer and Dunker 1981
slightly sodic		annual crops	ND	12 in	---	Halvorsen, Zimmerman and Melsted 1981
poor SAR = 20-30	loamy 1:1 clays	---	Northern Great Plains	12 in	may be adequate if the mine soils physical characteristic prevent upward salt migration	Dollhopf 1983
orphan mine overburden	---	---	southern WY	12-18 in	"satisfactory" cover not obtained unless 12-18 in	Singleton and Barker 1979
NW Colorado overburden	---	wheat; intermediate wheatgrass	---	18 in (or more)	yields increased from 0-18 in optimum may have been greater	McGinnies and Nicholas 1980
slightly saline	non-saline, non-sodic, loamy	cool season grasses	WY, MT, ND	20 in optimal	native require slightly more; optimal depth increases in wet years	Barth and Martin 1982
sodic	---	wheat grain	ND	20-28 in	yields did not increase when thickness exceeded 20-28 in	Power et al. 1981
medium EC<6 SAR<12	good topsoil	---	ND	24-30 in	landscape position as important as depth; 12 in topsoil over 12-18 in subsoil	Doll, Merrill and Halvorsen 1984
slightly saline	---	wheat, straw corn	ND	25 in or more	increased with each application of soil thickness	Bauer et al. 1978
sodic SAR = 25 dispersed	good topsoil slightly saline sodic subsoil	crested wheat and native grass; alfalfa spring wheat	central ND	28-36 in optimal	best results when topsoil was over subsoil; 8 in topsoil over <8 in subsoil	Power et al. 1981

Table 2.4-1 (continued)
SUMMARY OF SOME TOPSOIL DEPTH RESEARCH

Overburden Quality	Topsoil Quality	Land Use or vegetation	Region	Optimal Depth	Comments	Reference
---	---	native grass	WY	28-42 in	low precipitation regimes; 4-6 in topsoil over 24-36 in subsoil	Tresler 1974
---	---	---	---	greater than 30-40 in	maximum production with thin soil layer	Schuman and Power 1981
sodic SAR 28 clayey	non-saline, non-sodic, loamy	cool season grasses	MT and ND	32 in	annual and species varations can range from 28 in to 37 in	Barth and Martin 1982
coarse EC<6, SAR<12	good topsoil	---	ND	36-42 in	12 in topsoil over 24-30 in subsoil	Doll, Merrill and Halvorsen 1984
SAR 12-20	good topsoil	---	ND	36-48 in	12 in topsoil over 24-36 in subsoil	Doll, Merrill, and Halvorsen 1984
---	---	deep rooted crops	WY	40-46 in	higher precipitation regimes; 4-6 in topsoil cver 36 in subsoil topsoil over 36 in subsoil	Tresler 1974
SAR>20	good topsoil	---	ND	48-60 in	12 in topsoil over 36-48 in subsoil	Doll, Merrill, and Halvorsen 1984
strongly acid pH=4.0	non-saline, non-sodic, loamy	cool season grasses	WY, ND, MT	more than 60 in	maximum on yields occur at depths greater than 60 in	Barth and Martin 1982

Table 2.4-1 also shows that soil thickness required to reach maximum plant production increases as average effective precipitation increases. This is because overburden with adverse properties requires a soil covering thick enough to satisfy the nutrient needs of the vegetation and store precipitation and spring runoff at field capacity for plant use during the dry summer months (Hargis and Redente 1984).

The regulatory authorities depend on the type of research shown in table 2.4-1 to determine whether the soil reconstruction plan for a mine permit application is adequate. The regulatory authority should understand the nature of the spoil, the quality of the redressed soil, and knowing the average annual precipitation at the mine, find in writing that the plan affirmatively demonstrates that reclamation will be successful (30 CFR 773.15). Figure 2.4-1 is an unpublished model of topsoil quality, spoil quality, and topsoil thickness for the southwest, high desert ecosystem (personal communication, Fisher 1985). The model illustrates the concept of increasing soil depth dependent on soil and spoil quality (this particular model is not recognized or used by any regulatory agency).

2.4.3 Revegetation Success. Another method for evaluating the probability of successful reclamation at a proposed mine is to compare the proposed reclamation plan with similar active mines, and to judge whether revegetation has been successful or is showing encouraging results at those mines. "Similar" would mean mines with about the same average annual precipitation, vegetation species, thickness of redressed soil, and soil and overburden chemistry.

Minesoil Construction in the High Desert Ecosystem in the Southwestern United States Where Limited Soil and Regolith Available for Salvage

January 1984

	Good Topsoil	Marginal Topsoil	Coarse Textured Unsuitable Topsoil	Fine Textured (*) Unsuitable Topsoil
Good Overburden	12" of topsoil and no mitigation A	18" of topsoil with minor mitigation; consider substitution of overburden B	substitute overburden for topsoil C	substitute overburden for topsoil D
Marginal Overburden	18" of topsoil and no mitigation E	24" of topsoil with minor mitigation of topsoil; 30" without mitigation F	if overburden is coarse textured, substitute; if overburden is fine textured, 30" of topsoil with major mitigation G	substitute overburden for topsoil H
Coarse Textured Unsuitable Overburden	24" of topsoil and no mitigation I	24" of topsoil with major mitigation; 30" of topsoil without mitigation J	requires major mitigation effort with 24" of topsoil K	substitute overburden for topsoil; requires mitigation in plant root zone L
Coarse Textured Unsuitable Overburden with Major Mitigation	18" of topsoil with the major mitigation of overburden limitations M	18" of topsoil (minor mitigation) and major mitigation of overburden N	24" of topsoil with major mitigation of both topsoil and overburden O	extreme case - major mitigation with potential substitution of modified overburden P
Fine Textured Unsuitable Overburden (*)	30" of topsoil and appropriate mitigation, when possible, of overburden Q	30" of topsoil with minor mitigation; appropriate mitigation, when possible, of overburden R	extreme case, 36 to 48" of topsoil with major mitigation S	improbable case, reclamation uncertain T

(*) If the saturation percentage is above 85%, the problems and attenuate risks will be even more severe.

Soil Quality, Spoil Quality,
Topsoil Thickness Model

James P. Walsh & Associates, Inc.

figure 2.4-1

2.5 Soil and Overburden Reclamation Success and Bond Release Criteria

The success of spoil handling and soil reconstruction is usually evaluated during inspections based on the specifications in the permit. There are only minimal criteria for evaluating spoil handling and soil reconstruction for bond release, but reclamation must comply with the performance standards for grading and soil handling.

2.5.1 Recontoured Spoil. The bond release criteria for recontoured spoils specify that backfilling and grading must be accomplished in conformance with the performance standards; for example, achieving the permitted post-mining topography, the appropriate cover over deleterious spoil and any other performance specified in the permit.

The recontoured spoil surface serves as either a root zone or a substratum (below the root zone) for the reconstructed soil. Where the spoil will be the root zone, it is important to determine the characteristics that may affect reclamation. Where deleterious spoil may occur on the recontoured surface, the chemistry of the regraded spoil is determined by the recontoured spoil sampling program (section 2.3.4).

The reconstructed post-mining topography is compared to the post-mining topographic map. It is important that the topographic surface conform to the plan so that reconstructed soils are stable and capable of supporting their intended use. For example, soils reconstructed for cropland must have gentle slopes; rangeland soils are not as dependent on topography.

2.5.2 Reconstructed Soil Profiles. Thickness is the primary consideration during inspections in determining the success of soil handling and reconstruction. Thickness is considered adequate if it meets the pre-mine estimate of redressed thickness. The two states that require two lift topsoil handling also require that the lifts be replaced in the correct order. There are no state guidelines establishing more specific criteria for evaluating reconstructed soils for bond release.

In most cases, erosion of the redressed topsoil is evaluated qualitatively. Federal and state regulations require that rills deeper than 9 inches that form on regraded and topsoiled areas be filled, graded or otherwise stabilized. There also are requirements to minimize erosion and sedimentation that affect the surface water quality, but these are not measured with respect to soil erosion rates. One case study has quantitative erosion-runoff plots on reclaimed and undisturbed sites, specifically for the purpose of demonstrating reclamation success for bond release.

2.6 Soil and Spoil Monitoring

Many of the mines in this study have soil and spoil monitoring programs of some sort. These operators are typically monitoring one parameter, considered by the regulatory authority to be a possible problem, in response to a permit condition or stipulation. The operators are monitoring subsidence, trace element contents, salinity, sodicity, erosion, and the effects of irrigation water.

Although a lot of mines have research plots established, they are not considered routine monitoring in this report, because they are often not representative of current reclamation practice, the data may not be available to the state, the research objectives may not be directed at bond release, the monitoring is not consistent among mines, and these research plots do not entail a committment to long term monitoring (unless stipulated). The various state acts authorize the regulatory authority to require monitoring, if necessary, to evaluate compliance with the law, but none of the five states require it routinely. At mines where conditions are uncomplicated, reconstructed soil/spoil profiles are not being monitored on a routine long term basis (section 4.6).

2.6.1 Recontoured Spoil.

One of the case study mines (mine D) has a recontoured spoil subsidence monitoring program. The data are submitted in annual reports. There has been less than a foot of subsidence in five years.

Spoil chemistry is indirectly measured by the groundwater monitoring programs. This is a very important consideration discussed in the companion OTA report on hydrology (Western Water Consultants 1985). Spoil chemistry in the root zone is not being monitored on a routine basis, although several mines are monitoring becuase of stipulations and/or research objectives.

The recontoured spoil sampling programs (section 2.3.4) being conducted at many of the case study mines should not be considered monitoring because the sampling is conducted only once (although they are often referred to as monitoring). However, they are a measure of reclamation success (section 2.5.1).

2.6.2 Reconstructed Soils. Five of the mines of the study group have soil monitoring programs. Several case study mines are monitoring erosion (mines D, F, and J), two are monitoring soil salinity/sodicity (mines D and L), one is monitoring the effects of irrigation water on soil salinity (mine I), and one may monitor for molybdenum (mine C). Case study D has set up runoff plots on reclaimed and undisturbed ground. After each significant runoff event, runoff samples are collected, sediment yield measured, and erosion rate calculated for the plots. Case study J is using a semi-quantitative evaluation of soil erosion on revegetated surfaces every third year, and case study F has set up a small watershed monitoring program. Case study L is monitoring salinity and sodicity in reconstructed soils overlying sodic clayey spoil. In this case study, only 18 inches of soil were available to redress and concern was expressed that the overlying soil would be affected by sodium migration from the underlying spoil. Case study D is also monitoring sodium migration in thin topsoils (25 inches) over sodic spoil.

Montana has commissioned a study to evaluate methods for monitoring soil erosion from reclaimed surfaces as part of the bond release process (David Stiller and Associates 1983). Some of the methods available are surveys of sediment rates in sediment ponds (called bathymetric surveys), erosion pin surveys, runoff plots and sprinkler infiltrometer measurements. All of the methods have problems, and the state does not have an accepted procedure as yet.

2.7 Comparison of State and Federal Programs

The federal act requires that the state programs "meet the purposes of the act...and that the state laws and regulations are in accordance with the provisions of the act and consistant with the requirements..." (30CFR 732.15). A comparison was made between the state and federal programs for soils and overburden to determine if they are significantly different. A comparison was made between the federal act (SMCRA) and the five state acts (section 2.7.1) and between the federal and state regulations and guidelines (section 2.7.2). All five states in the study area have approved programs.

This comparison was difficult because similar issues are addressed by the states in different legislative or regulatory documents (i.e., acts, rules and guidelines) and the review was not exhaustive. The review found that in general, the acts, regulations and guidelines are quite similar but there are a few significant differences.

Table 2.7-1 shows selected differences between state and the federal surface mining reclamation acts. The New Mexico and Colorado acts are practically verbatim from the federal act. The table only shows selected differences and the articles have been abbreviated.

Table 2.7-2 addresses the regulations and guidelines concerning baseline data collection requirements and table 2.7-3 addresses performance standards. Similar requirements from the guidelines of some states and the regulations of another are combined on one table in order to compare programs. The table includes a guideline from Montana (DSL 1983) that is being rewritten in accordance with the revised federal regulations. It was the guideline in effect until 1984 and is now considered to be a draft.

2.7.1 Comparison of Acts. The requirements of the acts (table 2.7-1) are quite similar. A few articles are worded differently enough to have some minor effects on reclamation. For example, the federal act requires the proposed post-mining land use to be described including its capability to support a variety of uses (sec 508a). Four states have similar requirements (table 2.7-1) but the Montana act does not specifically mention this requirement. From various sections of the Montana act it is inferred that grazing is the use to which the land will be restored. Any other use is considered an alternative land use.

The federal act requires the land to be restored to a condition capable of supporting the uses which it was capable of supporting prior to mining (section 515b). The Wyoming act requires that it be restored to a use at least equal to its highest previous use. Proposed reclamation to other than the use prior to mining requires a change in land use procedures as described in the states' rules and regulations [ch II, sec. 3.b.(12)]. Where restoration of land capability was an issue (case study F), the land

Table 2.7-1
SELECTED DIFFERENCES BETWEEN FEDERAL AND STATE SURFACE MINING RECLAMATION ACTS

Federal 95th Congress, Public Law 95-87 1977	Colorado Colordo Legislature 1983	Montana Montana Legislature 1981	New Mexico New Mexico Legislature 1979	North Dakota North Dakota Legislature 1979	Wyoming Wyoming Legislature 1980
submit cross-section... depicting...nature and depth of the strata... (Sec. 507,b,14)	yes	thickness and geologic character...beginning with the topsoil (Sec. 82-4-222,1)	yes	yes	yes
the result of test borings or core samplings...including logs (Sec. 507,b,15)	yes	yes	yes	yes	log of drill holes not mentioned
chemical analysis of potentially acid or toxic forming...overburden... (Sec. 507,b,15)	yes	chemical analysis not mentioned	yes	yes	chemical analysis of overburden not mentioned
chemical analysis of the (underburden) (Sec.507,b,15)	yes	analysis of underburden not mentioned	yes	yes	analysis of underburden not mentioned
condition of the land... prior to any mining ...capability...to support a variety of uses (Sec. 508,a,2B)	yes	all known or readily discoverable past and present uses... (82-4-222,1)	yes	yes	general description of land ...shall include ... its past and present uses ... (land capability not mentioned)(35-11-406,a,vii)
productivity of land prior to mining... (Sec. 508,a,2C)	yes	yes	yes	productivity not mentioned	productivity not mentioned
use of the land following reclamation including... capacity to support... alternative uses (Sec. 508,a,3)	yes	plan...for the rehabilitation of the land... (post-mining land use not specifically mentioned)(82-4-222,1)	yes	yes	yes
a plan...for backfilling, soil stabilization, compacting, and grading and revegetation...(Sec. 508,a,5)	yes	yes	yes	yes	plans for surface gradient to a contour suitable for proposed use after reclamation...and proposed method (35-11-406,b,ii)
analysis of...acid forming properties of overburden (Sec. 508,a,12)	yes	specifics of analysis not mentioned	yes	yes	results of test borings not mentioned
restore...(the pre-mine capability)...or higher or better use... (Sec. 515,b,2)	yes	yes	yes	yes	...to a use at least equal to its highest previous use (35-11-402,a,i)

Table 2.7-1 (continued)
SELECTED DIFFERENCES BETWEEN FEDERAL AND STATE SURFACE MINING RECLAMATION ACTS

Federal 95th Congress, Public Law 95-87 1977	Colorado Colordo Legislature 1983	Montana Montana Legislature 1981	New Mexico New Mexico Legislature 1979	North Dakota North Dakota Legislature 1979	Wyoming Wyoming Legislature 1980
backfill, compact...and grade in order to restore the AOC ...with all highwalls, spoil piles and depressions eliminated...(Sec 515,b,3)	yes	depressions and AOC not mentioned	yes	yes	recontouring to assure reclamation of the land... (elimination of highwalls spoil piles and depressions not mentioned) (35-11-402,a,ii)
where the thickness of the coal deposits relative to the volume of the overburden is large... (Sec. 515,b,3)	yes	practices concerning insufficient overburden not mentioned	yes	yes	practices concerning insufficient overburden not mentioned
where the volume of overburden is large relative to the thickness of the coal deposit... and more than sufficient to restore AOC...the excess overburden...(Sec 515,b,3)	yes	practices concerning excess overburden not mentioned	yes	yes	practices concerning excess overburden not mentioned
may authorize...an experimental basis if...at least as environmentally protective... (Sec. 711)	yes	experimental practices not mentioned	yes	experimental practices not mentioned	yes
the RA shall require any permittee to make monthly reports...any necessary monitoring equipment or methods...(Sec.517,b,1)	mining and reclamation operations...board deems necessary to monitor (34-33-122,1)	may adopt rules with respect to the filing of reports... monitoring (82-4-205,7)	yes	yes	yes
approximate original contour not defined	the reclaimed area...closely resembles the general surface configuration of the land prior to mining... (34-33-103,3)	not defined	the reclaimed area ...closely resembles the general surface configuration of the land prior to mining... (Sec. 3,D)	the reclaimed area... closely resembles the general surface configuration of the land prior to mining... (38-14.1-02,2)	not defined
reclamation not defined in Act (only in regulations)	not defined	...backfilling, ...stabilization,... grading, topsoiling (82-4-203,25)	not defined	supporting the uses which they were capable of supporting prior to any mining (38-14.1-02,24)	reclaiming...to use for grazing, agricultural... (35-11-103,e,i)

capability for cropland (hay) was restored, even though it was seeded for native range at the request of the surface owner (section 4.3.3).

The federal act exempts excess and deficient overburden mines from certain performance standards (table 2.7-1). Originally, the regulations defined excess and deficient overburden on the basis of final spoil volume (vf) and initial overburden plus coal volume (vi). Where vf/vi was greater than 1.2 a thick overburden mine existed and excess spoil could be deposited out-of-pit; where vf/vi was less than 0.8 a thin overburden situation existed and the mine was exempt from the approximate original contour requirement. The Wyoming act and regulations did not have the same requirement (that excess be defined as vf/vi greater than 1.2 or that thin be defined as vf/vi less than 0.8) with the result that any excess spoil could be disposed out-of-pit. The federal definition of excess and thin has now been revised to be similar to the Wyoming regulations. The federal explanation of excess now reads "more than sufficient to restore...approximate original contour" and thin now reads "the spoil and other waste materials are insufficient ... to restore...approximate original contour" (30CFS 816.103).

SMCRA has provisions for experimental practices. Montana and North Dakota have no such provisions (table 2.7-1).

Conspicious by its absence from the federal act is any definition of reclamation. The Montana act defines reclamation as activities (backfilling, grading, topsoiling, etc.); North Dakota and Wyoming refer to capability to support a land use; and Colorado and New Mexico have no definition in their acts (table 2.7-1).

2.7.2 Comparison of Regulations and Guidelines. In the regulations of the five states there are a few major differences. Table 2.7-2 lists requirements for baseline studies. All five states require a soil map at

Table 2.7-2
SELECTED REQUIREMENTS FOR BASELINE STUDIES FROM REGULATIONS AND GUIDELINES

Item	Federal (30 CFR 700.1 1984)	Colorado (MLRD 1981 and MLRD 1983)	Montana (DSL 1980 and DSL 1983)	New Mexico (MMD 1980 and MMD 1984)	North Dakota (NDPSC 1983 and NDPSC 1984)	Wyoming (WDEQ 1980 and WDEQ 1984)
SOILS						
Map, base map requirements	yes (R-770.21)[1]	yes (R-2.04.9)	yes 1"=400' (G-I,B.2)[2]	1"=500' min.(G)	yes; 1"=400', (R-69-05.2-08-10)	yes; 1"=400'-700' (G-I,B)
Minimum size map unit delineation	not addressed	not addressed	1 acre minimum (G-I,B.1)	1/2 acre minimum (G)	not addressed	2 acre minimum (G-I,B)
Sampling intensity	not addressed	based on complexity (R-2.04.9)	3 representative locations (G-I,D.2)	up to 6 profiles (G)	not addressed	up to 3 profiles (G-I,B)
Depth of sampling	not addressed	not addressed	7 ft (G-I,D.1)	6 ft (G)	not addressed	5 ft (G-I,B)
pH, EC, Sat%, texture	not addressed	yes [R-(1)(b)]	yes (R-26.4.304)	yes (G)	yes (R-69-05.2-08-103)	yes (G-appendix 1)
SAR, ESP	not addressed	SAR (R-2.04.9)	SAR, ESP (G-I,E)	SAR (G)	SAR, ESP (R-60.05.2-08-103)	SAR (G-appendix I)
Se, B	not addressed	not addressed	Se, B (G-I,E)	Se, B (G)	not addressed	Se, B (G-appendix I)
Trace metals	not addressed	not addressed	not addressed	Mo, Cu (G)	not addressed	not addressed
Other	not addressed	other chemical analysis as required (R-2.04.9)	% OM (G-I,E)	$CaCo_3$ (G)	free lime %, %OM (R-69-05.2-08-10)	$CaCo_3$, coarse fragments dry and moist consistency NO_3-N, P, %OM, K, particle (G-appendix I)
OVERBURDEN						
Geologic map coal crop lines, strike-dip	yes (R-779.25)	yes (R-2.04.6)	not specified	yes (R-8-25)	yes (R-69-05.2-08-05)	yes (R-ch.II, sec.3)
Overburden isopach map	not specified	not specified	not specified	not specified	yes, (R-69-05.2-08-05)	yes (G-II,B)
Cross-sections; mined seams, rider seams, underburden	yes (R-779.25)	yes (R-2.04.6)	not specified	yes (R-8-25)	yes (R-69-05.2-08)	yes, (R-ch.II sec.3) delineate potential toxic zones (G-II,B)
Drill hole intensity	not specified	1 hole/640 acres, 3 holes minimum (G-table 3,B.1.)	1 hole/40 acres, more for suspect areas (G-III,D.2)	1 hole/150 acres, minimum of 3 holes; (G)	1 hole/40 acres (R-69-05.2-08-05)	up to 1 hole/80 acres; up to 1 hole/40 acres for special handling (at least two cores per section) (G-II,B)
Sample interval	not specified	4 to 10 ft (G-table 3.B)	not specified	2-10 ft (G)	5 ft (R-69.05.2-08-05)	5 to 10 ft (G-2,B)

Table 2.7-2 (continued)
SELECTED REQUIREMENTS FOR BASELINE STUDIES FROM REGULATIONS AND GUIDELINES

Item	Federal (30 CFR 700.1 1984)	Colorado (MLRD 1981 and MLRD 1983)	Montana (DSL 1980 and DSL 1983)	New Mexico (MMD 1980 and MMD 1984)	North Dakota (NDPSC 1983 and NDPSC 1984)	Wyoming (WDEQ 1980 and WDEQ 1984)
Quality assurance split sampling	not addressed	not addressed	not addressed	not addressed	not addressed	ea. 10th in triplicate ea. 20th by 2 other labs (G-II,B)(recently omitted)
Lithologic logs	yes (R-780.22)	yes (R-2.04.6)	yes (G-III,C.31)	yes (R-8-14)	yes (R-69-05.2-08-05)	yes (G-II)
Geophysical logs	not specified	not specified	not specified	not specified	yes (R-69-05.2-08-05)	1 geophysical log/1000 ft [GII,B)
Identify acid and toxic forming strata	yes (R-780.22)	yes (R-2.04.6)	yes (R-26.4.304)	yes (R-8-14)	yes (R-69-05.2-08-05)	yes (R-ch.II, sec. 2)
ESP, SAR	not addressed	SAR (G-table 3.A)	ESP, SAR	SAR (G)	SAR (R-69-05.2-08-05)	SAR (G-appendix I)
Se, B	not addressed	Se, B (G-table 3.A)	Se, B (G-III D.5)	Se, B (G)	not addressed	Se, B (G-appendix I)
ABP, sulfur forms	not addressed	pyritic, sulfate, organic, total (G-table 3.A.)	ABP may be requested (G-III,D.5)	ABP (for some samples) G SO_4 (R-8-14)	not addressed	APB (G-appendix I) organic carbon
Trace elements	not addressed	Mo, Pb, As, Cd, Fe, Mn, Cu, Hg, Zn (G-table 3.A.)	Mo (G-III,D.5)	Al, As, Ba, Cd, Cr, Co, Cu, Cn, Fe, Pb, Hg, No, Ni, Ag, So-4, U, V, Zn, Ra-226, Ra-228 (R-8-14) Mo, Cu, (G)	not addressed	As, Mo (G-appendix I)

Footnotes:

1 R - denotes topic addressed in regulations and the numbers following designate where it is discussed.

2 G - denotes topic addressed in guidelines and the numbers following designate where it is discussed. The Montana Guideline has recently been rescinded.

about the same scale and Montana, New Mexico and Wyoming describe the intensity of required mapping in their guidelines. Soil sampling intensity necessary to characterize soil chemistry varies from one to six profiles. There are other differences in required soil analyses shown on the table.

Four states require geologic maps showing coal croplines, strike and dip, but Montana does not. Wyoming specifically requires that cross sections delineate potentially toxic zones. Required drill hole intensities range from one hole per 40 acres to one hole per 640 acres. Wyoming did have a requirement to provide quality assurance samples for overburden analytical work, but it was recently rescinded. All four states require lithologic logs but only one requires geophysical logs. The trace elements required by New Mexico are in the rules whereas in the other states, trace metal requirements are in the guidelines.

Soil, topsoil, subsoil and suitable plant growth material (SPGM) are defined differently in the regulations (table 2.7-3). This is an important difference because it effects the material to be salvaged and the soil handling programs in every state. Federal regulations define topsoil as A and E horizons (30 CFR 701.5) and specify that "all topsoil shall be removed; where the topsoil is of insufficient quantity (other) materials approved by the regulatory authority" are salvaged (30CFR 816.22). North Dakota (NDPSC 1983) defines suitable plant growth material (SPGM) by its chemical suitability and requires that all SPGM identified by the soil survey (which extends to a depth of 5 feet) must be salvaged (Sec. 69.05.2-15). Colorado (MLRD 1981) defines topsoil as A horizons and portions of or all of the B and/or C horizons which are shown to be most suitable. Subsoils (B and portions of the C) are to be salvaged only if the Division determines that such material is necessary (Sec. 4.06.2). Montana (DSL 1980) requires all surface soils (A and possibly portions of B and C) and subsurface soils (B and C) to be salvaged (Sec. 24.6.701). New Mexico (MMD 1980) defines topsoil as A horizons or other suitable material. Subsoils (B and portions of the C) are to be salvaged "if the director determines that...it is necessary or desireable" (Sec. 1-5). Wyoming (WDEQ 1980) defines topsoil as "A, B and C soil horizons...which have been determined...to be suitable" and requires that "all topsoil...shall be removed" (ch 1, Sec.2).

In practice these differences in definition mean that in North Dakota where soils are typically deep, soils are often salvaged to 5 feet and mine sites are redressed to a minimum depth of 4 feet. In Colorado, the organic rich surface layers are salvaged and subsoils salvage is a site-specific decision. In Montana and Wyoming all suitable A, B and C horizon materials are routinely salvaged. In New Mexico where soils tend to be thin and of poor quality, all suitable materials including regolith are salvaged.

Table 2.7-3 compares performance standards for soil and overburden. The requirement to handle soils in one or two lifts is an important difference in the performance standards; Montana and North Dakota require two, the other states require one. All five states require uniform thickness, but Montana permits non-uniform application for special soil reconstruction (Sec. 2.3.5) and several states have permitted non-uniform distribution.

The required depth of cover over toxic or acid-forming material is variable. The federal regulations originally specified 4 feet, but this rule has been changed to "appropriate". New Mexico specifically states in their guidelines that mining is not precluded if 4 feet is not available.

Table 2.7-3
SUMMARY OF SELECTED PERFORMANCE STANDARDS
FROM REGULATIONS

Item	Federal (30CFR 700.1 1984)	Colorado (MLRD 1981 and MLRD 1982)	Montana (DSL 1980 and DSL 1983)	New Mexico (MMD 1980 and MMD 1984)	North Dakota (NDPSC 1983 and MDPSC 1984)	Wyoming (WDEQ 1980 and WDEQ 1984)
Soil, Topsoil, Subsoil, and Suitable Plant Growth Media (SPGM) definitions	Topsoil-A and E horizons (701.5)[1]	Topsoil-A horizons (portions of B and/or C most suitable (4.06.2) Subsoil-B and portions of C	Surface Soil- A (and possibly portions of B and C horizons) (24.6.701) Subsurface soil-B and C horizons	the A horizon or other suitable soil material (1-5) Subsoil-B and portions of C	first lift suitable plant growth material (69.05.2-15-02) (SPGM) second lift SPGM	Topsoil- A, B, and C horizons which have been determined to be suitable (ch.I,sec.2)
Soil material to be salvaged	all topsoil shall be removed. ...where insufficient...other materials... approved (816.22)	Topsoil. subsoil only if Division determines that such material is necessary... [4.06.2(3)]	All available surface and subsurface soil (24.6.701)	Topsoil. Subsoil...if the Director determines that...is necessary or desireable (20-22)	all SPGM (to a depth of 60 in.) (69.05.2-15-02)	all topsoil shall be removed (ch.I,sec.2)
Number of lifts	one (816.22)	one, B & C segregated if of good quality (4.06.(2)	two (26.4.701)	one (20-22)	two (69-05.2-15-02)	one (ch.IV,sec. 2)
Topsoil substitutes	yes (816.22)	yes, selected overburden materials (4.06.2)	yes (26.4.703)	yes (20-22)	yes, subsoil or other suitable (69-05.2-15-02)	yes, subsoil (ch.IV,sec.2)
Direct apply or stockpile	both (816.22)	both (4.06.3)	both (26.4.702)	both (20-21)	both (69-05.2-15-03)	both (ch.IV, sec.2)
Uniform thickness redressed	yes (816.22)	yes (4.06.4)	yes (26.4.702) variable depths permitted (G-II.c)	yes (20-24)	yes (69-05.2-15-04)	yes (ch.IV,sec. 2) (ch.IV, sec. 3)
Acid and toxic forming spoil	yes, identify, bury, treat (816.41)	yes, treat, bury, or compact (4.14.3)	yes, identify, bury, treat (25.4.641)	yes, identify, bury, treat (20-48)	yes, surface water diverted (69-05.2-18-01)	yes, identify, bury, treat prevent contact with water [ch.IV, sec. 3)
Depth of cover over acid and toxic forming strata	adequately covered (816.102)	specified by division (4.14.3)	8 ft minimum (26.4.505)	adequately covered (20-103) 4 ft minimum, mining not precluded if not available (Guideline)	4 ft minimum or not less than original cover (69-05.2-22-03)	4 ft minimum (ch.IV, sec. 3)

Table 2.7-3 (continued)
SUMMARY OF SELECTED PERFORMANCE STANDARDS
FROM REGULATIONS

Item	Federal (30CFR 700.1 1984)	Colorado (MLRD 1981 and MLRD 1982)	Montana (DSL 1980 and DSL 1983)	New Mexico (MMD 1980 and MMD 1984)	North Dakota (NDPSC 1983 and NDPSC 1984)	Wyoming (WDEQ 1980 and WDEQ 1984)
Thin overburden vf/vi	not specified (sec. 2.7.1 this report)	thin <0.8 (4.14.4)	not specified	thin <0.8 (20-104)	thin <0.8 (69-05.2-21.04)	not specified (ch. IV sec. 3)
Thick overburden vf/vi	not specified (sec. 2.7.1 this report	thick >1.2 (4.14.5)	thick >1.2 (26.4.511)	thick >1.2 (20-105)	not specified	not specified (ch. IV sec. 3)
Rills and gullies stabilized	depth >9 in (715.14)	depth >9 in (4.14.6)	depth >9 in (26.4.721)	depth >9 in (20-106)	if >9 in deep, (69-05.2-15-06)	depth >6 in unless found (ch.IV, sec. 3)
Alternate reclamation plan	not addressed	yes (2.06.2)	yes for post-mining land use other than grazing (26.4.821)	yes, for alternate post-mining land uses (9-23)	yes, for alternate post-mining land uses (69-05.2-23-03)	yes (ch.II, sec. 3)
Thickness of topsoil	not addressed	not addressed	not addressed	18 in (guideline)	not addressed	not addressed
Experimental practice	yes (785.13)	yes (2.06.2)	not addressed	yes (10-13)	yes (R-69-05.2-27)	yes (ch.IX, sec 1)
Post-mining land use	restore to equal or higher use (816.133)	equal to pre-mining land use, approved alternate use (4.16.1)	grazing...unless alternative use (26.4.762)	restore to equal or higher land use (20-133)	alternative post-mining land use may be approved (69-05.2-23-03)	greater than or equal to highest previous use (ch.IV, sec.2)

---

[1] Number indicates where topic is discussed.

3.0 CASE STUDIES

This section describes soil and overburden management at 13 case study mines. The climate, topography, land use, geology, and soils are different at each mine and the various approaches to baseline data collection, analytical techniques, soil and overburden handling, evaluating reclamation and bond release are presented for each case study.

Permit applications are the principal source of information for the case studies. Telephone interviews with the soil scientists or environmental coordinators at the mines were conducted, and the state personnel were interviewed concerning each mine.

Most of the case study mines were operating mines brought into compliance with the permanent regulatory program of SMCRA. They were selected for this study because they have reclamation results to evaluate but they may address the requirements of SMCRA in a different manner than new mines that commence the permitting process under SMCRA.

3.1 Case Study A

3.1.1 Introduction. Case study A is a surface coal mine in the Fort Union Formation in the Williston Basin of North Dakota. This mine was selected for study because, unlike any other mine in the studies, it has benign overburden, deep productive soils, gentle slopes, and adequate moisture. It is a control sample used to illustrate the permitting and reclamation process in the absence of special problems. It produces 5.5 million tons of lignite per year from multiple pits.

The average annual precipitation is 16 to 17 inches, most of which comes between April and September. Mean annual temperature is 40 degrees F, and the altitude is 1980 to 2080 feet. Slopes are undulating with a maximum slope angle of about 3.5 percent. The only complicating aspect of this mine is the lack of a well integrated drainage system on portions of the pre-mine surface. There are many closed depressions (potholes) typical of glaciated topograhy. The potholes are wetlands that are important to wildlife and most will be reconstructed and reclaimed.

The land is used mostly for dryland wheat production and about 10 percent of the permit area is used as rangeland. Some of the areas used for range have some limiting soil factors (typically shallow depth) that inhibit their use as a cropland. The post-mining land use will convert some of these rangelands to cropland at the stated request of the land owners. This is possible because the limitation of shallow depth to bedrock will be removed by the reclamation process.

The soils of the permit area are formed on nearly level to undulating glacial plains on friable, calcareous, alkaline loam or clay loam till. The geologic units in the permit area are the Coleharbor Group (Quaternary) and the Sentinel Butte Formation (Paleocene). The Coleharbor Group consists of a cobbly, gravelly, sandy, silty clay till with localized beds of sand and gravel. The till averages 25 to 30 feet in thickness. The Sentinel Butte Formation in the permit area has been eroded and only the lower portion is present. It consists of a thick channel sandstone overlying the coal beds. Interbedded siltstones and claystones occur below the coal. Two coal seams will be mined from the Sentinel Butte Formation.

3.1.2 Soil Inventory. A site-specific soil inventory of the site was based on a published SCS county survey. The inventory included detailed order two mapping, sampling, analysis and recommendations for stripping. The mapping was fairly intensive but the methodologies were not documented. Land capability (pre- and post-mining) is briefly described in the permit application in a qualitative manner.

The criteria for the two lifts for soil salvage are according to state regulations and most of the soils of the site are suitable to 60 inches of depth. A recommended salvage depth for the first lift is based on soil chemistry but the actual depth salvaged in the field is based on the color change between topsoil and subsoil.

3.1.3 Baseline Overburden Investigation. The geology of the site is described from the literature and an intensive drilling program. The overburden was sampled in 48 holes; approximately 30 acres per drill hole. Because of poor recovery, interburden was sampled at fewer (19) locations; approximately 80 acres per hole.

The overburden was tested for the standard agronomic properties; the laboratory methods were not reported. No data on acid potential or trace elements were provided, as is customary in this state. Acid potential or high levels of mobile trace metals are unlikely in the glacial till and unlikely (but possible) in the overburden or interburden of the Sentinel Butte. The average and range of values for pH, salinity and sodium adsorption ratio for the overburden and interburden were reported. There was no need to correlate geochemical values to particular strata as all values were suitable.

3.1.4 Overburden Handling. There are no special handling procedures for overburden at this mine. The calculation of overburden swell factor was a subject of debate during permitting. The agency stipulated that overburden swell be monitored, swell factors recalculated if necessary and the post-mining topography revised if necessary.

3.1.5 Soil Handling. Soil will be salvaged in two lifts as required by the state. There are no special practices to be used in topsoil redressing. At this site all material available for redressing will be used, providing an average of 18 inches of topsoil and 42 inches of subsoil. Topsoil will usually be stripped one year before disturbance; subsoils will be removed 6 months prior to disturbance to ensure that a large enough area is ready for overburden removal.

3.1.6 Prime Farmland. There was some discussion in the permitting process concerning a prime farmland determination. Approximately 50 acres of Bowbells loam (a prime soil) was mapped in a complex map unit on the site. According to the permit decision documents, after consultation with the SCS it was determined that these areas mapped as prime soil should not be recognized as prime farmland "since they were mapped in complex in the published county survey. Though not in conformance with the approved North Dakota state program" this determination was in accordance with the OSM in Denver and Washington, the Public Service Commission and the SCS.

3.1.7 Special Soil Reconstruction. Wetlands will be reconstructed at this site using the deep clayey soils salvaged from the potholes. These soils will be salvaged and stockpiled separately. They will be reapplied and compacted in depressions on the reclaimed surface in areas designed to receive run-on water.

As a permit stipulation, the applicant was required to develop a detailed plan to evaluate the reclamation of wetlands for the purpose of determining the release of performance bonds. The plan was to specify each wetland characteristic to be evaluated and each assessment technique to be used. The success of the wetland reclamation is being judged by an advisory panel of experts on regional groundwater, surface water, fish and wildlife and aquatic botany (Western Resource Development Corp. and Bunin 1985)

3.2 Case Study B

3.2.1 Introduction. Case study B is a dragline operation on the eastern edge of the Fort Union coal region in central North Dakota. The company operates four pits and is permitted for up to 3.8 million tons of lignite per year. The total mine acreage is about 4600 acres and about 250 acres are disturbed on an annual basis. The approximate average strip ratio is about 7.3 cubic yards of overburden per ton of coal.

The climate is typical of the cool, semi-arid Northern Great Plains with low to moderate humidity, moderate precipitation, warm to hot summers and cold winters. The native vegetation is a mixed prairie grassland with woody draws composed of deciduous trees and shrubs. The mine is on an upland terrace above a major river and includes some steep breaks.

The pre-mining land use is primarily rangeland (80%), but there are some croplands (15%), woodlands (6%), haylands (1.5%), and prime farmlands (less than 1%). The post-mining land uses will be similar to pre-mining land uses including cropland and prime farmland. A few small wetlands and woody draws will also be re-established.

The overburden at the site consists of the Holocene Oahe Formation comprising stream, lake and windblown sediments; the Coleharbor Group comprising gravel, sand, silt, and clayey till; and the Paleocene Sentinel Butte Formation of silt, clay, sand and lignite. Up to five lignite beds, 1 to 10 feet thick, will be mined at the site, and the overburden is 20 to 100 feet thick.

The soils of the mine areas are mostly deep, cool Mollisols of fine, silty, and fine-loamy textures formed over glacial till. There are some clayey, sodic soils. Soils with thick, dark surface horizons in loamy families occur in wet lowlands. Loamy to sandy, poorly developed soils occur on the steep breaks. Calcareous Mollisols formed on an upland till plain over a mantle of aeolian sands and silts. Badlands, scoria outcrops, and saline seeps occur scattered throughout the mine area.

3.2.2 Soil Baseline Studies. A soil inventory of the site included detailed order two mapping, sampling, analysis and recommendations for stripping. The sampling was fairly intensive but the methodology for sampling and analysis were not documented. The site contains a wide variety of soils including some problematic sandy aeolian, clayey and sodic, and badland soils. Some fine textured soils and some aeolian soils will be used, because North Dakota does not have an unsuitability criteria for texture (see table 2.3-1).

3.2.3 Overburden Baseline Studies. An overburden drilling and sampling program was conducted by the applicant. About 56 holes were cored, sampled at 5-foot intervals, and tested for pH, salinity,sodium adsorption ratio, and percent sand, silt and clay. The only interpretation made from the data was that much of the overburden was clayey and sodic, but there were no stratigraphic or geochemical correlations (see section 2.3.3). The permit application data indicate some strata from the surface to 30 or 50 feet are medium textured and non-sodic.

The acid-forming potential of the overburden was not determined, even though the permit application contained the statement that "the oxidation of pyrite is likely to be the primary process which will influence post-mining quality of spoil water." Black, carbonaceous shales were described but not correlated or handled in any special manner.

3.2.4 Soil Handling. The inventory sampled soils to 60 inches. At a later date the applicant was required to go back to an area of deep soils and sample from 60 to 96 inches to obtain additional material for use as suitable plant growth material. A permit stipulation required even more sampling in this area after permitting to define all available material in order to obtain 4 feet of suitable cover. The regulatory authority relaxed the soil use criteria in order for the operator to obtain enough material.

The operator suggests that clayey subsoils under loamy topsoils have better post-mining productivity than sandy subsoils under loamy or sandy topsoils. The operator is of the opinion that in reconstructed sandy soils (where sodium migration is not a problem) the spoil/soil interface should be closer than 4 feet to the surface to hold a perched water table within the root zone. To this end, they have preferentially salvaged clayey subsoils (as deep as 14 feet) and not salvaged sandy subsoils. They have also tried adding clayey materials to sandy materials to increase moisture holding capacity.

According to the applicant, the North Dakota requirement that prohibits mixing of soils from different landowners makes direct-haul topsoiling impossible at this mine.

3.2.5 Land Use. The land use plans at this case study are particularly interesting because there are prime farmlands, (non-prime) croplands, and wildlife habitat (woody draws and wetlands).

An area of prime farmland will be reconstructed at this mine. It has been hypothesized that landscape position is important to productivity on reclaimed soils in North Dakota (Doll, Merrill, and Halvorsen 1984). The prime farmland unit was placed on a concave portion of the landscape to maximize moisture accumulation in the form of snow and run-on.

The reclamation plan for non-prime cropland is not very different than reclamation of the rangeland because of the state's requirement for handling suitable plant growth material in two lifts and redressing soils to 5 feet.

It was originally intended that a major woody draw at this site would be mined and reclaimed, but the state refused to permit it and as a result the major woody draws will not be disturbed. A number of smaller woody draws will be disturbed and reclaimed, but no special handling of soils is entailed.

Wetlands will be established after mining in the form of small depressions that will intermittently hold water. The plan is being developed.

3.2.6 Recontoured Landscape. The design of the post-mining landscape and attainment of approximate original contour at this mine are based on pre-mining and post-mining slope class maps and acreages. There is no discussion in the permit of the geomorphology of the pre-mining surface or the surrounding landscape even though the post-mining surface is contiguous to a highly dissected terrace escarpment and badlands, and the post-mining surface is gently rolling with a low drainage density. There are a few steep, long slopes on the recontoured landscape.

The placement of prime farmland on a concave position on the landscape is an innovative use of post-mining topography to enhance a land use objective.

3.2.7 Standards of Reclamation Success. The productivity standards for the reclaimed prime farmland and non-prime cropland are based on long term SCS yield data for each soil series present in the areas to be affected. The productivity standard for wheat, for this disturbance, area is 15.5 bushels per acre, much less than the wheat yield already produced on reclaimed croplands during 1978 and 1979 (31 and 33 bushels per acre respectively). Power et al. (1981) determined on test plots at the mine that maximum yields for all crops tested (one of which was spring wheat) occurred when about 8 inches of topsoil was placed over 21 to 43 inches of subsoil. Post-mining croplands meet and exceed these topsoiling depths.

The applicant correctly points out that management of reclaimed croplands should be similar to normal farming practices on croplands under good management, but will not be excessive. These practices include the use of fertilizer, herbicides and insecticides.

3.2.8 Monitoring. Sodium and salinity are being monitored on a limited basis on research plots at this mine. According to the soil scientist on the site, they have not detected any sodium migration into the soil from sodic spoil, even where only 18 inches of topsoil have been redressed. The sodium and salinity content of the soil vary with the season and with time but no trends or problems have been detected.

3.3 Case Study C

3.3.1 Introduction. Case study C produces four million tons of coal per year in the Montana portion of the eastern Powder River Basin. It is a dragline operation mining two seams in the Fort Union Formation. The overburden consists of a massive sandstone unit underlain by claystones, and the interburden - which is important in this case study - is a grey shale.

The climate, vegetation, topography and land use are all typical of the region. The average annual precipitation is 15 inches, and mean annual temperature is 45 degrees F. Grassland and grassland-shrublands dominate the site, but there are some ponderosa pine woodlands on the buttes and ridges. The site has extensive gently sloping hillsides, narrow flood plains in wide shallow valleys, buttes with sandstone cliffs, and some badlands. Elevation is 3000 to 3500 feet. The pre-mining land use is rangeland.

3.3.2 Baseline Overburden. Drilling for the overburden characterization of this mine utilized 28 cores for 680 acres of mine area; an intensity of 24 acres per core, the highest of any of the case studies. The strata were sampled by lithology at intervals of 3 to 10 feet, and analyzed for a standard suite of agronomic properties plus cadmium, copper, iron, mercury, molybdenum, manganese, nickel, lead, selenium, and zinc. There are a lot of baseline trace metal analyses but almost no interpretation of the data.

3.3.3 Soil Inventory. The soil inventory was conducted in a manner similar to the other case studies and is not discussed further.

3.3.4 Interburden Special Handling. Double handling of dragline spoils was the major environmental issue at this mine for a number of years. The mine was permitted under a pre-SMCRA state law. At that time, high clay contents were considered unsuitable. The permit required that a grey shale interburden, considered unsuitable due to high clay, could not be spoiled in such a manner as to be found on the regraded spoil. This required a double handling of overburden spoil in order to make room deep in the overburden spoil for the interburden spoil.

In about 1973, personnel from the USGS (Erdman, Ebens and Case 1978) measured copper:molybdenum ratios on yellow and white sweet clover (molybdenum accumulators) growing on the site. It was suspected that the reported ratios were low enough (i.e., high molybdenum relative to copper) to cause molybdenosis in cattle. A review of some overburden data collected 4 or 5 years earlier found some extremely high levels (up to 179 ppm) of molybdenum. The samples had been collected using a pipe grease containing 10 percent molybdenum and the high values may have been the result of contamination (Neuman and Munshower 1983). The company collected more samples avoiding contamination, and the values were lower but still above the state's suspect level at the time (0.3 ppm).

A special study of the molybdenum problem was undertaken as a result of a permit stipulation to the 1979 permit. The study was conducted during the period 1979 to 1982 by the Agricultural Research Center (Neuman and Munshower 1983). It was found that "segregation of the interburden material did not have a statistically significant effect on the molybdenum content or copper:molybdenum ratios of the seeded plant species, when compared to vegetation grown on the mixed interburden area." As a result of this and other findings, the company requested that the requirement to bury the interburden be eliminated. Based on the regulatory authorities understanding that the interburden would be buried to a considerable degree over much of the remaining area to be mined, on the condition that the company submit a regraded spoil/vegetation sampling and analyses program for molybdenum on reclaimed areas and on a condition that problem spoil materials detected would be removed and/or buried, the request was granted in 1984.

3.3.5 Bluff Extension. This application contains an innovative post-mining topography that raises questions of approximate original contour, erosion control, uniform topsoil thickness, maximization of the coal resource, alternative reclamation and experimental practice. It is referred to as the "bluff extension alternative."

The operator revised the original application with a proposal to recover additional coal. This recovery would extend the mine pits into deeper overburden on the footslopes of some large bluffs. The bluffs are capped by a massive and thick (greater than 100 feet) sandstone bed which has eroded into irregular cliffs.

The final pit highwalls adjoining existing, undisturbed, competent sandstone will be retained to simulate the bluff face. Rather than backfill the final pit on a 5:1 slope to the top of the final cut, 50 to 100 feet of the highwall will be retained below which the final pit would be backfilled to the flattest practical slope.

The final highwall blast will be especially designed to maximize the roughness of the highwall for wildlife habitat and at the same time maintain competence. Rock rubble will be placed at the base of the highwall to improve wildlife habitat.

This alternative maximizes use of the coal resource. If the applicant were to mine into the bluffs and be required to reduce the highwalls to a maximum 5:1 slope, 1.5 million cubic yards of overburden would have to be cut back from the previously undisturbed bluff tops, essentially removing the original topography. This alternative was not considered economically viable by the applicant and if the bluff extension had not been approved, the additional coal would not have been recovered.

The plan was accepted by the regulatory authority as an alternative reclamation plan (Montana does not have an experimental practice provision in their act and this plan was not considered experimental). The regulatory authority found that the plan optimizes the use of the coal resource and achieves approximate original contour. It varies from the requirements to reduce all highwalls and redress topsoil. The plan minimizes erosion because the steep, short highwalls are capped by the resistant sandstone and the slopes at the bottom of the highwalls will be as gentle as possible. Reducing the highwalls to 5:1 would produce long slopes that would be much more erodible.

3.3.6 Recontoured Spoil Sampling. An innovative recontoured spoil monitoring plan has been proposed for this mine that involves the concept of monitoring vegetation trace metal content to judge the success of soil/spoil reconstruction. Because of the possibility of material with high molybdenum content occuring on the recontoured spoil, the applicant committed to a sampling program. The plan involves spoil sampling, vegetation sampling, and possible rehandling. First a 400-foot grid of recontoured spoil samples is collected to 8 feet and tested for pH, salinity, sodium adsorption ratio, particle size, molybdenum, and copper. If any of these samples are unsuitable, the unsuitable area is defined on a closer spaced grid (100 to 200 feet). If pH, salinity, or sodium adsorption ratio are unsuitable, the area is rehandled. If molybdenum is above 6 ppm the spoil is rehandled or covered. If molybdenum is between 2 and 6 ppm (above state suspect levels), vegetation transects will be monitored on the revegetated surface. If molybdenum levels in the forage become a problem for grazing animals, the affected area will have to be completely reconstructed.

3.3.7 Soil Handling. This company utilizes two lift direct-haul topsoiling. This system puts the biologically active topsoil on top of the reconstructed profile and eliminates the impact of long term stockpiling and double handling on the A horizon; the system is sometimes called "live handling."

The company reports the system is difficult to set up in the first years of a new pit in a dragline operation, but once in place it is not operationally difficult and for this mine is cheaper than stockpiling and rehandling. Haul distances are typically not longer than to a stockpile and back to the reclamation block. Fertilization is not needed. Two lifts does not add much expense as it only requires a small temporary stockpile of first lift material. In recent years almost all of their topsoiling is by this system. They are getting very good revegetation and they expect it will greatly improve their prospects for meeting the diversity standards necessary for bond release.

In the two lift direct-haul system at this mine, most of the soils are salvaged using the soil map without a staking program, as there are no major chemical soil constraints. The topsoil is salvaged to about 6 inches based primarily on color. The first lift (topsoil) is stripped from a band two or three scraper-widths wide, and temporarily stockpiled. The second lift (subsoil) is salvaged in that band down to a sandy residual layer just above the weathered sandstone bedrock. This lift is usually 18 to 24 inches thick. The sandy layer is detected by the equipment operators by its loose consistence. The subsoil is laid down on the recontoured spoil and then topsoil from the next band is placed over the subsoil. In the salvage area a three-step profile results with undisturbed soil, subsoil, and regolith exposed in parallel bands. On the last pass, subsoil is salvaged and redressed and then the topsoil from the temporary stockpile is put on top.

3.3.8 Special Soil Reconstruction. The company is also proposing an innovative special soil reconstruction method for establishing ponderosa pine. This technology is being borrowed from an adjacent mine, which is developing it in cooperation with the School of Forestry, University of Montana. According to the operator, the plan as originally proposed had poor success and was revised.

In areas where ponderosa pine woodlands are to be established, the underlying spoil will be compacted to retard the downward movement of water in the profile. Soils taken directly from ponderosa pine stands or coarse textured or clinker-type soils will be replaced over compacted spoil in two lifts. The subsoil and topsoil will be loosely applied and ripped to reduce any compaction. Planting will be done by hand.

3.3.9 Soil Volume Accounting. The state requires an annual soil volume accounting (a soil budget) for this mine. Each year, stripping depths are re-evaluated based on on-going salvage. The volume of soils in stockpiles, the volume remaining to be salvaged and the remaining area to be redressed are calculated.

The soil budget as of December 1983 indicates that approximately 1.5 feet of first and second lift material will be replaced; 6 to 7 inches of first lift and 12 inches of second lift. These numbers compare to a prediction during baseline permitting of 1.6 feet. The present soil budget shows that 94 percent of the volume predicted in the baseline studies is available.

The operator reports that the annual soil budgeting required by the state is a useful planning tool for both the mine and the agency. It facilitates the regulatory agency's compliance evaluation and allows the operator to assure the right amount of soil is being salvaged and that enough soil will be available for redressing in the final years of operation.

3.4 Case Study D

3.4.1 Introduction. Case study D is a large surface coal mine in the western Powder River Basin. It is a dragline operation mining about 8 million tons per year from a single pit. It is an 12 to 13 year old mine, permitted originally under the state mining act, and was one of the first mines permitted in Montana under the permanent regulatory program. Much of the data collection for the permit occurred in the mid-1970's.

The average annual precipitation in the mine area is about 12 inches, mean annual temperature is 42 degrees F, wind speeds average 8 miles per hour from the northwest and the elevation is 3400 to 3700 feet. About 45 percent of the moisture falls in the spring and 30 percent comes in the period October thru March. The native vegetation is sagebrush and grassland. The pre-mining land use was not discussed in the permit. Presumably prior to mining it was grazing, as is the proposed post-mining land use.

3.4.2 Baseline Geologic Information. The overburden is in the Tongue River member of the Fort Union Formation and consists of lenticular, poorly sorted sandstones, siltstones and shales. Two coal seams are mined; one is up to 52 feet thick and the other averages 18 feet. The interburden is about

39 feet thick. The overburden was characterized by 30 core holes; an intensity of 60 acres per hole. Cores were tested for the standard parameters required by the state and a dozen trace metals.

There is very little geologic information in this permit application. There are no geologic maps, laboratory methods, geophysical logs, delineation of deleterious strata, or stratigraphic correlations. There is essentially no evaluation of the geochemistry. The state technical analysis indictated that sodium adsorption ratios average about 28, with a predominance of finer textured materials. The state also indicated there were zones of high nitrate in a portion of the overburden which subsequent drilling confirmed.

3.4.3 Baseline Soil Inventory. A detailed soil inventory of the site was conducted. It included description, sampling, analysis and evaluation of the soil resource. The soils were not sampled by horizon but at 6-inch intervals in the topsoil and 12-inch intervals in the subsoils. The methods used were not well documented, but in other respects it was a standard pre-mine soil inventory.

3.4.4 Two Lift Topsoil Handling. As required by the state, soils will be salvaged in two lifts. The first lift is normally 6 inches, which in some cases includes some of the B or C horizon. Where A horizons are thicker than 6 inches, topsoils will be salvaged to 12 inches using scrapers. Subsoils will then be salvaged to the depth of a limiting factor; often salinity, sodium adsorption ratio or depth to bedrock. This depth is determined on the basis of a pre-stripping sampling and staking program. Where subsoils are suitable to depths as deep as 10 feet, they are salvaged using truck and shovel.

The operator reports that the soil survey was good, but that it does not reflect available volume within 10 percent. In one area the pre-mine survey showed about 1000 acres with a foot of suitable topsoil; the area was subsequently found to have soils suitable to only 4 inches due to a limiting chemical parameter (which is difficult to map in the pre-mining soil inventory).

3.4.5 Overburden Handling. The permit application contained a description for the special handling and burial of high nitrate zones in the overburden. According to more recent information, the applicant hopes this will not be necessary.

This permit did not require 8 feet of cover over sodic and clayey overburden. Materials to provide 8 feet of cover may not occur on the site, but there were some areas of favorable regolith and it was stipulated that these materials be used to provide 6 feet of suitable material under a reconstructed drainage way. This mine was an operating mine and one of the first permitted under the permanent regulatory program, and the regulatory authority suggested that if the mine were permitted today, the applicant would probably have to conduct more drilling for suitable cover material. The operator is monitoring recontoured spoil for unsuitable characteristics and reports that most sodium adsorption ratios are below deleterious levels (12) and they have not found any regraded spoil to be unsuitable. It is not clear why the pre-mine overburden studies showed overburden with an average sodium adsorption ratio of 28 (section 3.4.2) and the recontoured spoils are showing a much lower level.

3.4.6 Monitoring and Bond Release Criteria. This mine has three on-going monitoring programs and has been receptive to a lot of research.

A topsoil erosion monitoring program was designed by the operator and is being conducted; the operator indicated it was required by the state. Runoff plots have been built on representative reclaimed surfaces and in undisturbed areas. According to the mine hydrologist, "fair to good" data have been collected since 1981. The runoff plots are of simple design; sediment yield is calculated from total suspended sediment measured in a sample of runoff water following rainfall events. The applicant hopes to use a comparison of sediment yield from revegetated areas and the undisturbed areas to show that erosion control has been achieved for the purposes of bond release, and possibly to demonstrate that sediment ponds are unnecessary.

Subsidence has been monitored for 5 years. A minimum amoung (less than a foot) of subsidence has been observed on recontoured surfaces in five years according to annual reports.

Monitoring of sodium in redressed topsoil over sodic and clayey overburden was required by a permit stipulation. After two years there was no measurable upward migration of sodium from spoils into topsoil, but after seven years upward migration of sodium had occurred and mathematical prediction indicated topsoil may be sodic (SAR > 15) in 18-36 years (Dollhopf et al 1985).

3.5 Case Study E

3.5.1 Introduction. Case study E is a large (11 to 16 million tons per year) surface coal mine in the eastern Powder River Basin of Wyoming. The mine is a single pit, truck and shovel operation, that has been operating since 1972.

The site is typical of the region. Average annual precipitation is 17 inches, mean annual temperature is 45 degrees F, altitude is 4400 to 4700 feet, and the site is windy - mean annual wind speed is 12 miles per hour. The site has rolling uplands, scoria knobs, sandstone capped buttes, rock outcrops of sandstone and shale, and some sand dunes.

The pre-mining land use is 76 percent native grazing lands and improved pasture, 16 percent haylands and 7 percent croplands. Most of the site will be reclaimed to grazing land. Croplands will be reclaimed but haylands will not, and some grasslands will be reclaimed to shrublands to maximize wildlife habitat. The pre-mine croplands were used for wheat, oats and barley.

The overburden at this mine is Wasatch Formation and the coal is at the top of the Fort Union. The overburden thickness ranges from near zero to 260 feet and the coal is 70 feet thick; it is a deficient overburden mine.

3.5.2 Baseline Overburden. This application contained a thorough characterization of the overburden at the site. The overburden drilling program extended over a number of years. The core hole drilling intensity was 360 acres per hole. Cores were completely logged, sampled at 2 to 10-foot intervals depending on lithology and type, and analyzed for a complete set of agronomic parameters. Geophysical logs of the holes and complete documentation of analytical methods also were provided.

The applicant provided stratigraphic, lithologic and geochemical correlations. Geochemical data from silty shales, clay shales and sandstones were grouped and evaluated separately. The permit contained a detailed stratigraphic profile of the existing highwall (figure 2.2-5). The highwall map shows the degree of vertical and lateral continuity of the beds of the Wasatch Formation at this location; some of the units on the highwall are discontinous horizontally within a couple of hundred feet, but some are continuous on the highwall for 1000 to 2000 feet. The stratigraphic correlations between drill holes show some major strata extend over several thousand feet (figure 4.2-1). Even though the baseline study contains very good correlations, the permit application contains the statement that the strata are difficult to correlate. According to the applicant, correlations are easier on the portions of the permit area with massive sandstone units than where shales dominate.

3.5.3 Soil Inventory. The soil inventory at this site was the product of several different workers over a period of several years. Originally, three soil samples of each series were composited into one sample for laboratory testing, a practice since discontinued in this state. Most of the soils of the site are suitable to bedrock as a source of topsoil salvage. Because the soil survey of this site is typical of many similar case studies, it is not described further.

3.5.4 Soil Quality Versus Topsoiling Depth. This application stated that although "topsoil salvage depth is often emphasized as the most important criterion in providing suitable and sufficient plant growth material to meet the proposed post-mining land use...two better criteria are suitable plant growth material and quality replacement depth." A laboratory and short-term greenhouse study was conducted to show that the optimal salvage plan for several of the deep soils of the site would be to salvage the A, B and upper C horizons and leave the lower C horizons. The applicant maintained that the lower C was no different from the overburden and in some subsoils with high lime the overburden was better. The salvaged A, B, and upper C materials would be redressed over the 48 inches of suitable top bench cover material (see section 3.5.6).

The regulatory authority rejected this approach, stating that it "does not meet the requirements of all applicable rules and regulations. Although the C topsoil material in some of the soils is not as fertile as the A and B horizons, it is felt that the stripping of those suitable C materials will not appreciably reduce the quality of the replaced topsoil."

3.5.5 Topsoil Handling. The applicant proposed a uniform topsoil depth; an average depth of about 19.8 to 20.7 inches but also noted that there will be annual variations in topsoil thickness and about a 15 percent settling factor; sandstone soils reapplied at 22 inches thick will settle to about 19 inches.

During the last two years, a two lift direct-haul topsoiling method has been used. Excess soils are being stockpiled because the mine is operating in an area of deep soil, and some soil must be stockpiled to provide the necessary volumes for redressing in areas of the mine where soils are thinner in order to maintain uniform thickness.

3.5.6 Overburden Handling. Most of the overburden strata at this site have no deleterious qualities. A few of the strata are potentially acid forming (according to acid-base potential testing) or have low pH, and some overburden materials near the draws are saline.

The deleterious overburden handling plan consists of a pre-drilling program, special handling if indicated, the use of near surface materials as the last 4-foot spoil lift, a recontoured spoil sampling program, and 4 feet of suitable cover where necessary. A pre-drilling program samples the top bench material on 500-foot centers. The data gathered in this drilling program are used to delineate deleterious strata but are also used for delineating wet areas, defining highwall stability, planning shovel moves, and other operational considerations. If the pre-drilling program identifies deleterious strata comprising more than 20 percent of the bench, the material will be placed in areas of high clay or silty shale backfill so they will have no contact with air, surface water, reconstructed groundwater aquifers, topsoil or vegetation. To limit oxidation of carbonaceous shale, coal stringers, and coal partings, these materials will be buried below the projected water table in the backfill, where they will be covered quickly with compacted overburden.

The recontoured surface is backfilled to within 4 feet of the final level with run-of-mine spoil. The final 4 feet of spoil is near-surface, coarse-textured, oxidized, suitable spoil. The recontoured spoil surface is sampled to 4 feet on a 660-foot grid (10 acres) to assure suitability. To date, all of the recontoured spoil samples analyzed have been suitable using this mining method. If an unsuitable sample were found, the area would be delineated and either covered, treated or removed. This operation has become standard practice for truck and shovel mines in the Wyoming Powder River Basin.

3.5.7 Land Use. In Wyoming, regulations (chapter II, Sec. 2A) require the applicant to describe and rank the previous uses of affected lands on an individual basis according to the overall economic or social value of the land use to the area or local community. The applicant stated that "low crop yields and high operating costs make tillage agriculture a break even or net loss operation in most years." Land uses at the site were therefore ranked as follows: 1) hayland (improved pasture), 2) grazing land, 3) cropland, 4) water resources and 5) wildlife habitat.

3.6 Case Study F

3.6.1 Introduction. Case study F is very large truck and shovel surface coal mine in the eastern Powder River Basin of Wyoming. The mine produces 20 million tons of low sulfur sub-bituminous coal a year from a single pit.

The climate is dry, cool and windy. The average annual precipitation is 12 inches, mean annual temperature is 45 degrees F, and the mean wind speed is 8.5 miles per hour. Most (75 percent) of the moisture comes from April to September. The vegetation communities are grasslands and shrublands. The site is gently rolling with some steep-sided gullies and washes and a few playas. The pre-mining land use was rangeland except for about 155 acres which at one time was used for dryland wheat. The site is within a National

Grassland administered by the U.S. Forest Service.

The site overburden consists of alluvium and Wasatch Formation with interbedded and lenticular clays, silty and sandy clays, thin discontinuous coals and silty and clayey sandstones. The coal is the Wyodak-Anderson "O" seam which marks the top of the Fort Union Formation and has some thin coal partings. The coal varies from 10 to 70 feet in thickness but averages 66 feet, and dips 2 or 3 degrees west toward the center of the basin.

3.6.2 Baseline Overburden Characterization. About 30 core holes were used to characterize the overburden of the site for the baseline studies. The operator is committed to drilling additional holes to bring the entire site to one core per 160 acres. A second stage of development drilling is also being conducted, without a set grid pattern but based on experience, which averages about 1200 to 1800 feet between drill holes (33 to 75 acres per hole). A third stage of drilling is conducted in problem areas using blast holes drilled on very close centers.

For baseline studies, core holes were sampled in varying degrees of intensity; sample intervals ranged from one to 70 feet. Samples were analyzed and laboratory methods were referenced. The analyses indicated that nitrates, pH, acid-base potential, texture, sodium adsorption ratio, and salinity were parameters of concern. These were correlated to benches; sodium adsorption ratio, exchangeable sodium percent and salinity were of concern on the uppermost bench; unsuitable pH and acid-base potential, in the upper and lower benches; and unsuitable nitrate-nitrogen occurred on the lowest bench.

The application also contains a detailed geologic map.

3.6.3 Baseline Soil Inventory. A soil inventory was conducted in the late 1970's as part of a permit application. The inventory contained many large complex soil map units; the mapping was not considered adequate for the purpose of soil salvage by the regulatory authority. The mapping was upgraded in 1982 and the map units were refined. The final inventory contained many monotaxonomic soil map units; but percentages of inclusions were not given.

The original inventory had one soil sampling location per series. This was also upgraded in 1982 to three locations per series to conform with new guidelines. The soils were analyzed for some very unusual parameters including hydraulic conductivity, air-water permeability, modus of rupture, settling volume and moisture equivalents.

This application referenced the soil inventories at two adjacent mines as sources of information. This is one of the few instances of the use of data from other permit applications.

3.6.4 Overburden Handling. Overburden is removed in 50-foot lifts with 36 cubic yard shovels and 170 ton trucks and backfilled in approximately the same sequence as it was removed. If greater than 15 percent of a mine bench is phytoxic, the bench is specially handled. This entails mixing, varying bench thickness, transferring to an alternative pit as a middle bench and providing 4 feet of suitable cover if necessary. During current operations, the operator has identified in certain areas an acid-forming, orange-stained rider seam, about 20 to 40 feet below the ground, which is blended and kept 4 feet below the recontoured surface. Scalping materials are put in the middle of the backfill and kept 30 feet below the surface. An attempt is made to keep all unsuitable materials 8 feet below the recontoured surface.

3.6.5 Recontoured Spoil Sampling. This operator attempted to implement an innovative recontoured spoil sampling program. Originally, regraded spoils were sampled on a 500-foot grid pattern. Where unsuitable samples were found, the operator sampled in concentric circles around it, but found that due to the high amount of variability, unsuitable areas could not be delineated. In the opinion of the mine soil scientist, the unsuitable areas are less than 50 feet in radius.

A new system was devised because the soil scientist did not believe that a 500-foot grid was adequate to detect unsuitable areas that were less than 50 feet in radius. Under the new plan, grab samples are collected from about 10 locations in a 5 acre parcel. At each location samples are collected from the intervals 0 to 2 feet and from 2 to 4 feet. The intervals are composited from the 10 locations into 2 samples representing the 0 to 2 and 2 to 4-foot intervals for the 5 acre parcel. According to the mine soil scientist, this system takes more time but probably gives a better representation of the recontoured spoil. According to the regulatory authority, compositing has the potential for obscuring small, unsuitable areas when unsuitable samples are mixed with suitable samples and the procedure has not been approved.

Unsuitable parameters observed to date at this mine on recontoured spoil are generally sodium adsorption ratio, salinity, and occasionally acid-base potential, indicating the baseline studies were adequate to predict which parameters would be above suspect levels on the recontoured surface.

3.6.6 Soil Handling. The limiting factors for soil use on this site are sodium adsorption ratio, clay percent, selenium, salinity, and depth to bedrock. This applicant proposed not to salvage poor quality C horizon material and in this case (unlike case study E) the regulatory authority concurred. The regulatory authority concluded that the poor quality C material would not add very much volume and would diminish redressed soil quality.

Topsoils are staked on 200-foot centers prior to stripping. Each stake represents 1 acre, which when multiplied by depth in feet gives volume in acre-feet which, according to the soil scientist, is useful in volume calculations. The volume to be salvaged will provide 25 inches for redressing.

The operator reports that the volumes calculated from the original survey are fairly accurate for five-year areas but less accurate for smaller areas. He estimates the original survey is accurate to about ± 20 percent.

Soil is being stockpiled and redressed in one lift at this mine. The operator reports that based on bids from contractors, direct-haul is more expensive, but he feels that it would not be more expensive if it were incorporated in the mine plan.

3.6.7 Research. A study of erosion of a small, reconstructed drainage system is being planned at this mine. The intent is to use a sediment monitoring program to show that post-mining erosion levels are similar to pre-mining levels. The operator believes that judging reclamation success will be a fairly qualitative process.

3.7 Case Study G

3.7.1 Introduction. Case study G is located in the southern part of the Powder River Basin. It is a large surface coal mine producing 3.7 million tons of sub-bituminous coal from three pits. It is a dragline and scraper operation, with scrapers handling 10 percent of the overburden. The mine has been in operation since 1958.

This area of Wyoming gets about 10 to 14 inches of precipitation a year. There is a bimodal distribution of precipitation with maximums in May or June and in Septemer or October. The average annual wind speed is 13 miles per hour and as a result evapotransporation rates are high. There are buttes and low rolling hills and some badland topography in the mine area. The pre-mining and post-mining land use is exclusively rangeland and wildlife habitat.

Unlike most of the coal mines in the eastern Powder River Basin that remove overburden of the Wasatch Formation and mine coals at the top of the Fort Union Formation, this mine removes two coals from the Wasatch. The coals are taken from different pits so there is no interburden as such. The overburden consists of unconsolidated or weakly consolidated coarse grained arkosic, feldspathic sandstones with interbedded claystones, or conglomerates and sandstones with interbedded shales. The strata are gently dipping.

The soils of the site are mostly shallow to moderately deep. Sandy loams occur over arkosic and silicious sandstones. Clayey soils developed over shale. Silty loam and silty clay soils have developed over siltstones. Deep, fine textured soils formed on alluvium.

The quality of information in this permit application, gathered in the 1978 and 1979 field seasons and presented to the agencies in 1980, appears (to this reviewer) to be very good. As more information became available during operations, the original data were refined, according to an environmental manager at the site.

3.7.2 Soil Inventory. During 1978 through 1979, a very intensive baseline soil inventory was conducted on high quality orthophoto base maps with topography. Soils were not correlated to established series. The operator found the survey to be inadequate for the purpose of topsoil salvage, and the mapping was refined in 1983 by a soil inventory using mapping unit transects.

Initially one pedon of each soil was sampled to a depth of up to 10 feet. In 1983, more pedons were sampled as deep as 22 feet for each of the five most extensive soils to bring the survey into compliance with a new guideline. As a result there are a lot of soil analytical data. Soils were tested for the standard suite of agronomic properties; a few soils were analyzed for selenium where indicator plants were present. Due to the deep sampling or possibly due to actual pedologic differences, there is also more soil available for redressing at this site than is typical for the region.

Each mapping unit was evaluated for a weighted-average topsoil depth. A single stripping depth for each map unit in 6-inch intervals is given. An average depth of 34 inches of soil is to be redressed in one lift. The applicant uses a computerized topsoil map and mine plan overlay to calculate all topsoil disturbance areas and volumes.

3.7.3 Baseline Overburden Characterization. The applicant had 74 core and rotary drill holes which were sampled for overburden analyses in the life of mine area. Detailed lithologic descriptions, numerous cross sections with stratigraphic correlations and geophysical logs were provided.

Generalized correlations were provided in the permit application and made between geochemistry and stratigraphy, for example:

- "high nitrate zones generally occur within 50 feet of the ground surface";
- "limited zones of high molybdenum....generally occur within 50 feet of the top of the coal";
- "the majority of high acid-base potential zones occur in orange to beige, coarse grained, unconsolidated sandstone strata directly above the lower and upper seams, but other minor zones do occur in other areas."
- "Zones of high ABP are depicted in plates ____ of the permit application."

Lab analyses were conducted for the standard set of agronomic properties and trace metals over a period of time by four different labs. Acid-base potential was run only on a small percentage of the samples prior to 1980. About 22 percent of the samples tested were unsuitable by state standards for one or more parameters. As much as 80 to 90 percent of some individual drill holes were considered unsuitable. The application contains 135 pages of overburden analytical data, roughly 25,000 data points.

There was an apparent problem with contamination of some of the overburden samples with zinc-based pipe grease.

3.7.4 Delineation of Deleterious Strata. The overburden baseline data indicated samples unsuitable for the criteria of pH, acid-base potential, nitrate-nitrogen, boron, molybdenum and saturation percent. The acid production problem is the most serious, and because acid-base potential was only run on samples with a low pH (according to state guidelines prior to 1980) the extent of the problem is not well defined by the baseline data.

The application contained a map showing unsuitable areas based on drill hole data; the area surrounding any individual hole with more than 5 percent of the strata above suspect levels was considered to be unsuitable. This is very conservative in contrast to case study F which used 15 percent (per bench) and case study H which used 20 percent per drill hole.

Additional drilling and analyses were required by the regulatory authority as a permit stipulation "to more closely delineate problem materials and provide a more accurate estimate of the volumes of suitable material available for necessary cover, including drainages." The regulatory authority apparently believed that the original program may not have detected some unsuitable strata for two reasons: the drill hole spacing is probably too large to adequately delineate deleterious strata and acid-base potential was run only on low pH samples (prior to 1980). The applicant was given two years to provide data from a drilling intensity of one hole per 80 acres. A progressive program of pre-disturbance drill hole data on 500-foot centers also was required.

Extensive overburden drilling has been going on for several years since permitting. There was some question during permitting whether there was enough material to provide 4 feet of suitable cover over the mine area plus 20 feet of cover over reconstructed drainage ways. The regulatory authority and the operator report this question has been resolved favorably since permitting.

3.7.5 Special Overburden Handling. Based on data available when the permit was issued, some special handling of deleterious strata within the limits of the dragline would be used at this mine. High nitrates generally occur within 50 feet of the surface. These will be placed high in the regraded spoil by the supplemental stripping equipment or by a modified dragline swing to keep it above the predicted post-mining groundwater surface. According to the permit, zones high in molybdenum will be specially handled only if molybdenum in regraded spoil becomes a problem.

The mine does not have a plan for special handling of acid-forming material because, as a dragline operation, it is not practical. The applicant will rely on recontoured spoil sampling to identify areas that are unsuitable for root zones. The plan specifies regraded spoil sampling on a 500-foot grid to a depth of 4 feet in 2-foot intervals and testing for all required parameters including acid-base potential. One staff member of the regulatory authority expressed the opinion that he would have preferred a 200-foot grid, and feels that some "hot spots" will be missed using this 500-foot grid.

3.7.6 Topsoil Handling. The topsoil redressing at this operation will not be in uniform thickness but will range from 2.4 to 5.1 feet. Areas with deep soils prior to mining will be redressed with deeper soils than areas of thin soil i.e., post-mining soil depth will vary, as did pre-mining soil depth. The applicant states they will not haul topsoil long distances to achieve uniform thickness. Direct placement of topsoil will be practiced whenever possible, but is impractical for most of the operation, according to the operator. A request for a minimum application depth of 12 inches was denied by the regulatory authority.

3.7.7 Research and Monitoring. There has been extensive research at this mine. Soil and overburden research has been conducted on erosion, acidic spoils, topsoil depth requirements, micorrhiza, spoil swell and settling. There are erosion studies on native and reclaimed surfaces. These studies are used for planning but are not yet related to bond release, according to the operator. Various amendments are being tested on acidic spoil in hopes of avoiding the requirement for 4 feet of cover. The mine is monitoring swell (estimated to be 30%) and settling. One staff member reported that, in these sandy overburden materials with dragline spoiling, settling might be a problem and that certain areas may have to wait up to five years before topsoiling. The company states that most settlement problems can be easily corrected and that re-topsoiled surfaces can be monitored for cracks and corrected as necessary.

3.7.8 Post-Mining Landscape. This application has an excellent analysis of pre-mining and post-mining geomorphology, too extensive to describe fully here. The purpose of the study was to produce a stable post-mining landscape that minimizes sediment production that would not have occurred naturally. The plan considered pre-mining and post-mining drainage networks, drainage basins, drainage densities, reclaimed drainageway erosion, valley slope and valley width factors. Each reclaimed major drainageway was individually designed. A research program on the reclaimed geomorphology is underway.

3.8 Case Study H

3.8.1 Introduction. Case study H is a moderate size surface coal mine in the Hanna Basin of Wyoming. It is permitted to produce three million tons of sub-bituminous coal per year from 8 seams mined from 15 pits. It is a combination dragline, truck and shovel operation.

Low precipitation, strong winds, and short growing season make this a cold, arid site. The average annual precipitation is 10.4 inches, mean annual temperature is 42 degrees F, altitude is 6500 to 7530 feet, and the winds are strong, averaging 13.9 to 8.9 miles per hour from the north and west respectively. Forty percent of the precipitation falls during April, May and June.

Rolling plains broken by low hogback ridges characterize the permit area. The native vegetation types are sagebrush and grass on the uplands, sagebrush in the bottoms, and the rough breaks are nearly barren. The pre-mining and post-mining land use is rangeland and wildlife habitat.

The soils of the site are deep to shallow. The deep soils in the draws are from 40 inches to 8 feet deep and are fair to good sources of plant growth media. The surface layers are loamy and relatively rich in organic matter. Moderately deep soils on uplands are 20 to 40 inches deep and are fair to good sources of material. Rocky areas with very shallow soils (less than 10 inches) and saline-alkaline soils are unsuitable for use in reclamation.

The geology of the site is complex. The overburden and coals to be mined are in the Hanna Formation which is steeply dipping and faulted at this location. The predominate rock type is sandstone with varying amounts of shale, carbonaceous shale, siltstone and interbedded sandstone and shale.

3.8.2 Baseline Overburden Investigation. The description of the regional geology was based on published literature and a regional USGS map. The site-specific description of overburden was based on the drilling program, and consisted of a line of core holes drilled 2000 feet apart along the position of the final highwall (down dip). At 6000-foot intervals (every third hole) one or two more holes were drilled up dip and perpendicular to the original line. The cores were described by a professional geologist and samples were collected by lithologies at intervals required by the state and ranging from 2 to 30 feet.

The samples were tested for the standard suite of agronomic properties, selenium, boron, nitrate-nitrogen, molybdenum, and copper as well as exchangeable sodium percent and acid-base potential in a few samples. Overburden testing was carried out by four different labs over a period of years and different criteria were used to evaluate suitability as the guidelines were being revised frequently by the regulatory authority. According to the applicant, high sodium adsorption ratio is the parameter of most concern, and high values generally occur above the coal bed.

The areas of unsuitable overburden were delineated on a map. Areas of influence (polygons) are delineated around each hole. The polygonal area is considered unsuitable if more than 20 percent of the tested strata (by thickness) are unsuitable or when more than 50 percent of the strata are poor by state criteria.

3.8.3 Soil Inventory. An unpublished SCS county survey was used as the basis for a soil inventory of the site. The detailed inventory was an order two survey conducted in a manner typical of the other permit applications reviewed in this study. The mapping consisted mostly of complexes with some consociations, scale was 1:6000 (1 inch = 500 feet), and minimum size delineation was 2 acres.

In the original inventory each soil type was sampled at one location. At a later date it was necessary to conduct additional sampling to bring the sampling intensity up to three sample locations per series or two per map unit as per revised guidelines. The soils were tested for the normal suite of agronomic properties.

The land capability units of the soils of the permit area are reported, but there is no specific discussion of post-mining land capability. The SCS determined that some of the soils of the site were capable of being prime farmland, but in the absence of a developed irrigation system it was found that these soils were not prime.

3.8.4 Topsoil Handling. The topsoil handling plan calls for uniform distribution by mining block, but non-uniform distribution across the permit area. Redressed topsoil depth will range from 1 to 23 inches.

There was some question during permitting regarding mixing of topsoils and subsoils and use of poor quality C material. The applicant's soil consultant suggested segregating some topsoils from subsoils. The applicant however, did not propose to segregate topsoils, or salvage C horizons. The regulatory authority noted that a one lift handling system would mix good and fair material with poor but this was acceptable due to the undeveloped nature of the soils and the impracticality of segregation. However, the regulatory authority required the applicant to salvage the C horizon materials that were suitable.

3.8.5 Overburden Handling and Recontoured Spoil Sampling. A plan was developed to address problems of unsuitable overburden. The regulatory authority suggests that there is significant acid-forming potential in the strata of the site. According to the state decision documents one drill hole with 27 percent pyritic strata and considerable acid-forming material occur in the overburden. Many black, coaly and carbonaceous materials occur in the interburden and above the coals in the overburden. Most of the overburden is spoiled without special handling by the dragline. Truck and shovel operations will dispose of thin (less than 10 feet thick) partings in the interburden in a truck dump, but thick partings and deleterious strata in the overburden will be spoiled by the dragline.

The applicant's deleterious material handling plan is based mostly on a recontoured spoil sampling program. The applicant originally proposed to conduct recontoured spoil sampling in areas where the baseline drilling had indicated unsuitable areas (greater than 20 percent unsuitable or 50 percent poor). The regulatory authority felt that some unsuitable strata may have been missed in the initial drilling because of the drill hole spacing, because only a few samples were tested for acid-base potential (as per state requirements at the time) and because of problems in the acid-base potential data itself. According to the operator additional drilling was being conducted in areas of unsuitable overburden, but was discontinued as not being effective.

In the current plan (not yet approved by the regulatory authority), spoils will be sampled on a 625-foot grid (one sample per nine acres). If unsuitable samples are identified, the surrounding spoils will then be sampled on a 200-foot grid (one sample per acre). According to the operator, this sampling intensity was justified on the basis of previous sampling on a 200-foot grid which did not show much variability. Unsuitable areas identified by the spoil sampling program will be buried under 4 feet of cover, removed or treated.

The recontoured spoil sampling program is a subject of debate. Similar problems have been addressed at other mines in the state by requiring additional overburden drilling in the entire mine area, sampling on a progressive basis during blast hole drilling, special handling (by truck and shovel), or more intensive (500-foot grid) spoil sampling. At least one staff member of the regulatory authority is dissatisfied with the drilling, data and monitoring, and expects there will be long-term acid problems in the reclaimed surface at this mine. The operator does not consider acid formation to be a potential problem, but rather considers sodium adsorption ratio to be the limiting parameter in the spoil, and questions the rationale behind the entire recontoured spoil sampling program.

3.8.6 Intensity of Drill Hole Spacing. When the regulatory authority expressed concern about the adequacy of the overburden characterization baseline study, the applicant conducted an experiment at a nearby mine to show the adequacy of its program. In an area that had been previously mined and recontoured using the proposed mining techniques, three cores collected prior to mining were evaluated by the required analytical methods and found to be unsuitable. The recontoured spoil from that area was then sampled on about a 200- foot grid; 110 samples were collected and tested for the required analyses. Only three samples of the recountoured spoil were found to be unsuitable. The applicant concluded that the mining method and mixing would prevent unsuitable materials from showing up on the recontoured surface.

3.8.7 Excess Spoil. Excess spoils exist at this mine because the final volume of spoil is greater than the initial overburden plus coal volume. This excess overburden will be disposed of on the low wall side of the pit, outside the pit limits. At the time, the federal regulations (since revised) required that excess overburden exceed 1.2 (final to initial volume ratio) in order to allow out-of-pit disposal. Wyoming did not have a similar requirement in their regulations and this difference allowed for out-of-pit disposal (section 2.7.1).

3.9 Case Study I

3.9.1 Introduction. Case study I is a large surface coal mine in the Green River-Washakie Basin. The overburden and coal are in the lower part of the Fort Union Formation. It is a multiple seam, combined dragline, truck and shovel operation removing eight million tons of coal per year, and up to 260 feet of overburden and interburden from up to five seams.

The site is arid, windy and cold, one of the harshest sites in this study. Mean annual precipitation is only 6.5 inches, and average annual wind speed is 10.9 miles per hour from the west. The topography consists of rolling hills, narrow valleys, small sandstone escarpments, and terrace remnants. The vegetation is desert shrubs and grasses.

The soils of the site are mostly in orders Aridisols and Entisols. They are typical calcareous residual soils, stratified alluvial soils, and dune sands. The textures range from clayey to coarse-loamy and gravelly. Most of the soils are calcareous in some part of the profile and many are saline and alkaline.

One staff member of the regulatory authority states this is a very environmentally concerned company, getting very good reclamation results, in spite of the fact that it operates at one of the harshest sites in the state.

3.9.2 Baseline Overburden Characterization. The overburden characterization program at this mine was fairly detailed and the methods used are typical. Drill holes were described and sampled on an intensity of 160 acres per hole for most of the mine, and sampled for the usual parameters as well as acid-base potential, nitrate-nitrogen, and exchangeable sodium percent. The samples were also tested for molybdenum, boron, selenium, and arsenic.

The overburden is dominated by sandstones that weather into loams or silt loams. It was found that exchangeable sodium percent, boron, salinity, and low pH were above suspect levels in some of the strata, and nitrate-nitrogen, molybdenum, and acid-base potential were suspect in a few strata. About 28 percent of the overburden and interburden strata were considered unsuitable.

The deleterious geochemical values were correlated to particular zones in the stratigraphy. The applicant indicated that toxic- or acid-forming material found at the site are in the top 20 feet of overburden, the 30 feet above the top coal seam, and the interburden. The applicant also states that carbonaceous zones are so minor in thickness and distribution that mixing during conventional dragline operations will mitigate any problems associated with carbonaceous materials. However, the data on acid formation are not complete because acid-base potential tests were conducted only on samples with low pH through 1980 (as per existing guidelines).

At the time of permit approval, overburden drilling had not been completed on the southern portion of the mine to the required density. Initial drilling was done on 1-mile centers. The applicant committed to bringing the entire mine site to the density of one drill hole per 160 acres before mining occurs in any particular area.

3.9.3 Soil Inventory. The topsoil inventory for this site was conducted according to standard practices and is not discussed further.

3.9.4 Topsoil Handling. This topsoil handling plan contains a provision to redress topsoil in a two lift direct-haul system where practical. It is estimated that direct-haul topsoil will be used on 50 percent of the area. The average topsoil thickness for the 9700 acres of affected land is 17 inches. The applicant estimates that there will be a 10 percent topsoil loss due to handling and repair of gully and rills. Research by Argonne National Labs at this mine showed that revegetation diversity was about four times greater on areas using direct-haul topsoil than on areas with stockpiled topsoil (Jastrow _et_ _al_. in press).

3.9.5 Deleterious Overburden Management. The management of deleterious overburden at this mine consists of identifying unsuitable strata, special handling of unsuitable strata, a recontoured spoil sampling plan, and a guarantee of 4 feet of cover over deleterious spoil.

A baseline drilling program cored overburden at intensity of 160 acres per hole for most of the mine. More drilling was conducted in unsuitable areas [defined as holes with more than 15 percent (by volume) of unsuitable material]. These areas were upgraded to one hole per 100 acres minimum. This stage of drilling utilized exploration drill holes or blast holes for cuttings. In truck and shovel areas, suitable strata were further refined by drilling on 400-foot centers to the depth of the pre-strip bench in order to delineate materials for use as cover.

Special handling of deleterious strata will be used to the extent practical based on equipment limitations. Coal cleanings are routinely disposed in the bottom of the pit. Dragline mixing should dilute areas with less than 15 percent unsuitable materials. A modified dragline swing will be used where operationally practical to place unsuitable materials at the base of the spoil pile and to minimize its occurrence in the root zone. In the truck and shovel operations, suitable materials will be used as cover for recontoured spoils where necessary, and unsuitable materials will be buried.

A recontoured spoil sampling plan is used to assure that deleterious spoil will be covered or otherwise treated. Samples at 2-foot increments to a depth of 4 feet are taken on 400-foot centers and analyzed for a complete suite of paramters. If a sample is unsuitable, additional samples are taken at 100-foot centers and tested for the unsuitable parameter to delineate the unsuitable area.

The unsuitable spoil is then either covered or disposed of. The first option is to move 4 feet of material from an adjacent regraded spoil area onto the unsuitable area. If that option is not viable, material is taken from the pre-strip area, moved across the pit, and applied directly to the unsuitable area. If neither option will work well, the unsuitable material will be removed and buried in the pit.

3.9.6 Reclamation Results. This operator reports that the soil survey conducted for the baseline studies was very good. They use a topsoil staking program in the field but do not do additional analyses.

A fleet of equipment assigned specifically to reclamation, improves the quality of the reclamation at this site, according to the environmental coordinator. Some of the scraper operators have five to six years experience on the site. This dedicated fleet allows the operator to schedule reclamation activities at the most opportune times.

In the last two years, all of the soil handling has been done as a modified two lift direct-haul; 9 inches of subsoils are taken out of stockpiles and 6 inches applied directly. The operator reports that the advantages of two lifts are obvious, and they try to avoid stockpiling whenever possible. With this dedicated fleet, direct-haul is not operationally difficult and does not add expense. The operator reports that it is the soil volume that determines most of the expense; longer hauls may be involved in direct-haul but this is offset by the elimination of the double handle.

This operator has proposed to use a non-uniform topsoil thickness; they propose to put 12 inches on the ridges and 30 inches in the swales to recreate the pre-mining soil configuration. The operator contends that the requirement for uniform topsoil replacement is hindering the achievement of vegetation diversity. According to the operator, the regulatory authority has informally agreed to this proposal.

According to this operator the regulatory authority ought to be more flexible on the soil use criteria. One of the principal reclamation species used at this mine, Gardner salt bush, is very tolerant of boron. There are reconstructed soils with boron above the state's suspect levels, with good stands of re-established Gardner salt bush.

3.10 Case Study J

3.10.1 Introduction. Case study mine J is situated in the mountain shrub ecosystem of northwestern Colorado. The company produces about 4 million tons of bituminous coal per year out of several mines, but this study addresses only the main operation. The mine is a dragline operation removing an average of 20 feet of overburden; maximum overburden depth is 120 feet.

The site receives about 16 inches of annual precipitation and the mean annual temperature is 40 degrees F. The mine is on a hogback ridge, mining the dip slope (6 or 7 degrees) at an elevation of 7200 to 7700 feet. The native vegetation is big sage, aspen, and mountain shrubs. Pre-mining land use is mostly rangeland but there are some fields that were cropped and put back into pasture prior to mining. The site contains some aspen woodlands that provide wildlife habitat.

The coal is in Williams Fork Formation of the Mesa Verde Group in the Green River Basin. The Wadge is the main coal seam to be mined but the thinner Fish Creek Coal and the poor quality, thin Lennox seam also will be extracted where possible.

The soils of the site are typical mountain loams; cool, loamy Mollisols under oak brush and service berry shrubs. Soils are shallow on steep side slopes and deep and fine textured on the alluvial bottoms and in the draws.

3.10.2 Overburden Characterization. The overburden characterization at this mine was without complications. About 37 rotary holes were drilled, giving a fairly high intensity of 92 acres per hole, and sampled in intervals from 10 to 30 feet for the thickest beds. The samples were analyzed for a complete set of agronomic properties and a list of 13 trace metals. A few samples were considered above suspect levels in lead, molybdenum and nickel but there were not enough suspect samples or values high enough to require additional investigation. A complete statistical analysis of the overburden data was provided showing mean, standard deviation, standard error, coefficient of variation, minimum, maximum, range and frequency; the trace element data were presented on histograms to give a very good picture of trace metal distribution in the samples, but no relation was established between rock types or stratigraphic zones and geochemistry.

3.10.3 Soil Inventory. The SCS conducted the soil inventory for the applicant, which is unusual, and it was not as detailed as most of the inventories reviewed. The permit application states it was an order two survey, but it appears to be similar to SCS order three. Additional sampling was required at a later date to supplement the original mapping and sampling.

The soils were tested for the usual agronomic parameters and evaluated according to the existing Wyoming state criteria (Colorado has no published guidelines). All the soils tested were chemically and physically benign except for a few stoney or clayey subsoils.

According to the permit, soils would be salvaged on the basis of A and B horizons; that is A horizons would be salvaged first and B horizon next, and the soils would be direct-hauled where practical or stockpiled separately if necessary. The estimated average depth of redressed topsoil was 21.3 to 24.5 inches.

3.10.4 Soil Handling. A large mulcher is used to remove the woody vegetation, slash it into mulch and incorporate the mulch into the topsoil. This equipment can operate in the aspen woodlands, producing as much as 77 tons of mulch per acre. The mulch is left on the surface of the undisturbed soil and incorporated into the soil during handling.

In some areas of the mine, topsoil is live handled using a two lift direct-haul method. The soils are salvaged to 18 to 21 inches. At least 12 inches of subsoil (lower A or mixed A and B horizon materials) soil is laid down prior to replacement of the surface layer. The top 6 to 9 inch surface layer is then replaced on the surface of the reclaimed area. The operator feels that direct-haul is by far the most economical method of soil handling and gives the best reclamation results.

The soil scientist at the mine does not agree that two lifts are necessarily better than one. His in-house data indicate no difference in cover or productivity between 14 inches of mixed A and B compared to 7 inches of A horizon material over 7 inches of B horizon. He states that the assumption that topsoil over subsoil is better, may not be universally true. He argues that uniform requirements for reclamation practice may not be appropriate at any given mine.

The soil scientist also contends that with 50 or 60 tons of mulch per acre, erosion is not a problem. The regulatory authority however, reported that this mine has some serious topsoil erosion problems on long, steep slopes with heavy textured soils. The practices of chiseling and contour furrowing were inadequate on these slopes and the applicant put in diversion ditches.

3.10.5 Overburden Handling. No special handling of deleterious overburden is used at this operation. The mine has two permanent overburden piles where 22 million cubic yards of excess spoil are disposed.

3.10.6 Land Use. A few fields around the mine shop were used prior to mining for wheat or oats. The soils were marginal and the growing season is too short to reliably produce wheat crops, and after about 10 years of production the croplands were turned back to pasture. These lands will be returned to pasture during reclamtion, and no special soil reconstruction will be used prior to mining for wheat or oats. The soils were marginal and the growing season is too short to reliably produce wheat crops, and after about 10 years of production the croplands were turned back to pasture. These lands will be returned to pasture during reclamation, and no special soil reconstruction will be used.

3.10.7 Monitoring. This applicant is conducting regular, long-term semi-quantitative monitoring of erosion of reclaimed areas. Soil conditions are evaluated according to a BLM system that quantifies soil erosion of features such as rills, flow patterns, gullies, soil movement and deposition, pedestalling and the presence of surface litter. The soil erosion is rated as low to severe based on the frequency and intensity of the observed features (BLM 1972). Inspections are made every third year during the bond release period in conjunction with the collection of vegetation data.

3.11 Case Study K

3.11.1 Introduction. Case study K is a small, truck and shovel surface coal mine in the Colorado portion of the San Juan Basin. It will produce 250 thousand tons of bituminous, low sulfur, high BTU coal from multiple (3) seams in the lower Fruitland Formation. The largest case study mine produces in a few days what this mine produces in a year. The operator estimates an overburden swell factor of 33.3 percent and has a thick overburden situation. A new pit is developed every couple of years at this mine and the box cut spoils are placed in the old pit.

The average annual precipitation at this site is 15 to 20 inches; mean annual temperature is 45 to 48 degrees F, and altitude is 6400 feet. About 15 to 45 percent of the precipitation falls as rain in May, August and September. The native vegetation is mountain shrub and pinyon-juniper. The mine is on ridges in a steep sided canyon.

The overburden at this site consists of alluvial terrace gravels, and shales, siltstones and sandstone of the Kirtland Shale, and interbedded sandstone, siltstone, shales, and carbonaceous shales of the Fruitland Formation.

The pre-mining land use is rangeland, wildlife habitat, and some dryland pasture. Twenty acres of rangeland will be changed to pasture to increase the ability of the land to support livestock husbandry. Total estimated disturbed area for this permit is 70 acres, some of which is on U.S. Forest Service land.

3.11.2 Baseline Overburden. Several cross sections with some overburden correlations were provided. The overburden chemical data consists of one hole, slightly outside of the permit area, with 6 samples. The samples were analyzed for the usual suite of agronomic properties plus 12 trace metals. There is no analysis of the data except for the statement that there are no acid- or toxic-forming strata.

3.11.3 Soil Baseline Inventory. A detailed soil inventory and sampling of the permit area was conducted according to National Cooperative Soil Survey standards. Most of the area of the mine pit has no suitable topsoil, because the soils are too steep, shallow, and stoney for salvage. The only sources of soil on the site are deep alluvial soils in a few draws. The estimated redressed topsoil thickness is 6 inches applied in one lift of uniform thickness. The available volume of topsoil is minimal and a stipulation was issued requiring that all available topsoil be salvaged and that a minimum of 6 inches must be redressd.

3.11.4 Soil Handling. The applicant is obtaining the required 6 inches of soil from the salvage area. Originally soils were salvaged and stockpiled but now the operator is able to direct-haul, and about 15 percent of the mine will be reclaimed using this system. The operator prefers direct-haul because finding room for stockpiles is a problem in this permit area.

Soil erosion was considered to be a problem during the permit application process. The permit contains provisions to use contour furrowing and terraces on slopes of 2.5:1. The operator reports good erosion control results on a nearby recontoured surface using contour furrows on 2.5:1 slopes.

3.11.5 Excess Overburden. This applicant has had difficulty with the regulatory authority concerning swell factors and excess overburden. Published literature and the lithologic logs were used to calculate a swell factor of 33.3 precent. The regulatory authority required additional information and a study was conducted using an aerial survey. A comparison of net fill volume with net excavation volume yielded a swell factor of 33 percent. This still did not satisfy the regulatory authority and a stipulation was issued requiring annual aerial or field surveys to verify the swell factors and conformance with the approved post-mining topography.

3.11.6 Land Use. A portion of the permit area is privately-owned dryland pasture. This area and about 20 additional acres of rangeland will be reclaimed to pasture to increase the ability of the land to support livestock husbandry.

The portion of the site on U.S. Forest Service land will be reclaimed to wildlife habitat using Pinon and juniper.

3.12 Case Study L

3.12.1 Introduction. Case study L is a moderate size surface coal mine in the San Juan Basin of New Mexico. The mine is permitted for 3.5 to 4.5 million tons of coal, to be produced from four pits in a combination dragline, truck and shovel operation.

The average annual precipitation at this site is only 6 inches. The mean annual temperature is 52 degrees F and the elevation is 5000 to 5300 feet. Winds average 5 miles per hour. Half of the moisture falls from July to October. The native vegetation is grasslands and shrub-grasslands. The pre-mining topography consists of a dissected plateau which slopes gently to the west, low mesas, buttes and a broad valley associated with a large arroyo.

The pre-permitting use of the land, besides coal and scoria mining, was exclusively rangeland of very poor quality. The post-mining land use will be rangeland, with a subordinate use of wildlife habitat and some permanent structures.

The soils of the site are typical desert Aridisols and Entisols. Upland soils are coarse-loamy, gravelly and fine-loamy textures. Alluvial soils in various textural families (from coarse to fine) and dune soils are common. Sodium affected soils in fine-loamy families occur on the site.

Two coal seams near the bottom of the Fruitland Formation will be mined. The overburden consists of fine to medium grained sandstones, siltstones, carbonaceous claystones, sandy and silty claystones, bentonitic claystones and coal. The interburden consists of siltstone, sandstone, shale and carbonaceous shale. The interburden is 110 feet thick and the average depth of overburden is 150 feet.

3.12.2 Soil Inventory. An order two soil inventory was conducted for the permit application. The mapping was at a scale of 1:12000 (1 inch equals 1000 feet) and was more general than is typical for a pre-mine soil inventory. Mapping included many complexes and the delineations generally were quite large. Soils were sampled and analyzed in a standard manner. One detailed pedon was described and sampled per soil series.

3.12.3 Baseline Overburden Characterization. The baseline overburden drilling program consisted of fewer test holes than is typical. Nine core and rotary drill holes, approximately one per section (640 acres), were sampled at 2-foot intervals. The samples were tested for a standard set of agronomic properties plus a very large number of trace elements including: aluminum, arsenic, barium, cadmium, chromium, cobalt, copper, iron, lead, mercury, molybdenum, nickel, selenium, silver, vanadium, and zinc. There were about 40 pages of trace metal analytical data with no interpretation of the results. Acid-formation is not considered to be a potential problem in this state (by industry or the regulatory authority) and there was no discussion of the pyritic overburden or black carbonaceous shales which were described in lithologic logs.

There were no geophysical logs, stratigraphic correlations, geochemical correlations, or delineation of deleterious strata, possibly because it was concluded that essentially all of the overburden is deleterious due to high sodium adsorption ratio and high clay contents. Further drilling, analysis or interpretation was not considered to be productive. Data from nearby mines operated by the same company also suggested this to be the case. However, additional drilling and sampling of regolith (weathered bedrock) on a progressive basis was required as a permit stipulation (section 3.12.6).

3.12.4 Cover Over Toxic Materials. It has been suggested by some environmentalists, that this mine (and other mines in the area) did not meet the requirement to cover toxic materials with 4 feet of cover. The federal requirement has since been revised to read " appropriate depth of cover." Toxic in the federal regulations is described as "chemically or physically detrimental to biota ...". Under this loose definition, materials with high sodium adsorption ratio could be considered toxic, but there was no written definition of toxic in the state at the time. In addition, 4 feet of cover simply was not available.

The applicant contends that non-saline, sodic spoils (materials with high sodium relative to calcium and manganesium but low total sodium and other salts) are not toxic to adapted species. The applicant argued that 4 feet of cover were not required over sodic spoil because there was no suitable material available, native species were adapted to the conditions, and sodification of overlying topdressing was not a concern. The agency found that the application complied with all current regulations. However, a topsoil sodium monitoring plan was required as a permit stipulation.

3.12.5 Topsoil Inventory Evaluation. The original survey showed a less than adequate volume of material was available. The regulatory authority, in order to provide for additional volumes of topdressing material, relaxed the criteria for topsoil salvage. This allowed use of saltier, more sodic materials (with a pH less than 9.0, salinity less than 16.0, sandy loams or coarser with sodium adsorption ratio less than 20.0, and boron up to 5 ppm). These criteria are less restrictive than is typical, but were considered appropriate by the regulatory authority because of the natural soil chemistry. Soil volumes were recalculated using the relaxed criteria and 10.8 inches of suitable topsoil were shown to be available.

The regulatory authority requested additional sampling to determine the accuracy of the original survey. The applicant therefore excavated 254 pits (14 acres per pit) and re-evaluated topsoil availability. The original survey turned out to be remarkably accurate as the re-evaluation showed that 11.2 inches were available.

3.12.6 Regolith Study. The regulatory authority suggested that 11.2 inches of topdressing material was not sufficient due to the high sodium adsorption ratio of the spoil and suggested that 18 inches would be better. According to the applicant, there are no data to show that 18 inches is better than 11 inches with non-saline sodic spoils in arid precipitation regimes.

Nonetheless, a regolith study was required by the regulatory authority to further delineate suitable materials. This study consisted of about 17 deep (20-foot) pits. This delineated two isolated bodies of suitable regolith and provided about 6 inches more of suitable material. This brought the total volume of topdressing material available to almost 18 inches and the regulatory authority approved the plan. However, a topsoil staking program and a regolith monitoring program were required. The applicant objects to the regolith monitoring program because (according to the applicant) the areas of suitable regolith already have been delineated and that even if suitable regolith is found, there is no way to salvage it given equipment schedule limitations.

3.12.7 Topsoil Handling. This operation uses a two lift topsoiling system with non-uniform thickness. Topsoil and subsoil will be redressed in two 4-inch lifts to a depth of 8 inches over benign spoil (sodium adsorption ratio of less than 20 and a clay content of less than 28 percent). In most of the mine, where sodium adsorption ratios average 53, topsoil and subsoil will be redressed to a depth of 18 inches in two lifts of 4 inches and 14 inches respectively.

A topsoil staking program precedes soil salvage. A 15 percent soil loss factor was applied to estimates of topsoil volume. An annual topsoil volume budget is required by special stipulation to monitor the topsoil volume situation at the mine.

The applicant opposed the use of mulch in this environment in their permit application. Their research indicates that mulching is expensive, causes contamination with weeds, is not needed under irrigation, may be detrimental to seed germination, is only effective as an erosion control agent during the short period between seeding and establishment of healthy seedlings and ties up nitrogen that otherwise would be used for plant growth. A permit stipulation requiring mulching on slopes of greater than 6.5:1 and/or heavy soils (clay content greater than 28 percent) with slow water infiltration was issued. The method of determining where on the spoil those areas occur was not specified.

3.13 Case Study M

3.13.1 Introduction. Case study M is a small (200,000 tons per year) mine in the San Juan Basin of New Mexico. The mine operates as a combined small dragline, truck and shovel operation out of one pit on a permit area of about 600 acres. The mine is on a section of state land, and was permitted under the state program without the OSM's parallel review. The application was the subject of an unsuccessful unsuitability petition and a law suit by an environmental group. The case study description is based on the permit and supplemental material at the state office, but not on additional material submitted as part of the law suit (and on file with the court), some of which was used as a basis for the permit decision, according to the regulatory authority.

The site is arid, average annual precipitation is about 7.5 inches, mean annual temperature is 50 degrees F, and the elevation is 5800 feet. About half of the moisture comes in September, October, and November. The pre-mine site topography was about half badlands and half gently sloping shale barrens.

According to the applicant, the pre-mining land use was very limited grazing. According to intervenors in the permit application process the principal pre-mining land use was scenic, recreation and scientific. At the time of permitting the site was bounded on three sides by a wilderness study area (now a national wilderness area). The post-mining land use will be very limited grazing. According to the permit "badlands as such will not be reclaimed."

The operation is mining three seams in the Fruitland Formation. The overburden consists of sandstone, siltstone, shale and carbonaceous shale. Soils are absent from most of the site. The surface materials are bare outcrops of vari-colored shales with thin resistant beds of sandstone and siltstone that act as ledge formers and pedestal formers.

3.13.2 Baseline Overburden. Geologic information provided by the applicant in the permit application and supplemental information was minimal; there was no use of published information, of offsite drill hole information, or information from other mines in the same formation. There was essentially no description of the site-specific geology. There was no geologic map and the cross sections showed only the surface topography and the coal seams; overburden strata were not shown.

About 50 exploration holes were drilled, but overburden chemical data came entirely from two core holes; an intensity of 330 acres per hole which was consistent with state regulations at the time. From these holes, one word lithological descriptions of strata were given, for example "shale." From these two core holes about 20 subsamples were collected and composted into 9 samples. These 9 samples were tested for the complete list of parameters specified by the state regulations including the 23 trace metals specified. All the samples were determined to be unsuitable due to high sodium adsorption ratio (ranging from 32 to 121).

3.13.3 Baseline Soils Inventory. The soil inventory was conducted in parts at two different times. The southern half of the area was part of a survey of 5000 acres conducted at a scale of 1:24,000, probably too small a scale for pre-mine inventories. The northern half of the site was surveyed later at a larger and more appropriate scale (1:1600). Most of the site was mapped as badlands or shale barrens.

The permit application contained an innovative approach to evaluating soils for use in reclamation, which is described in section 2.3.1.

3.13.4 Reclamation Plan. All of the surface materials were determined to be unsuitable and the applicant proposed not to salvage or redress any material. However, the regulatory authority required the use of substitute topdressing material. A sandstone stratum, represented by two composite samples with sodium adsorption ratios of 32 and 38, was proposed for use as an alternative topdressing material. The reclamation plan called for the special salvage, stockpiling, and redressing of the sandstone unit. A permit stipulation required this material to be redressed in two lifts to a depth of 14 to 18 inches as a substitute topsoil material. In supplemental information submitted by the applicant, an isopach map showed the thickness of the sandstone stratum to be over 10 feet.

Intervenors unsuccessfully argued that two composite samples from two holes showing "sandstone" with high sodium adsorption ratios was insufficient data on which to base a reclamation plan. The regulatory authority felt that these two samples probably were representative of the strata at the site, based on experience elsewhere in the basin.

3.13.5 Approximate Original Contour. The New Mexico regulations for general grading requirements state that "...all disturbed areas shall be returned to their approximate original contour...and graded to eliminate all spoil piles, depressions..." (20-101). " The final graded slopes shall not exceed in grade either the approximate pre-mining slopes....(and) post mining final graded slopes need not be uniform but shall approximate the general nature of the pre-mining topography..." (20-102). The regulations define approximate original contour to be "that surface configuration achieved...so that the reclaimed area...closely resembles the general surface configuration..." (sec.3,D).

The pre-mining topography at this site consisted of a gently sloping (less than 5 percent) area in the southern part of the section and badlands in the northern portion. The badlands are a complex of highly dissected, high drainage density, mesas, buttes, pillars, and rock tables. Pre-mining slopes in the badlands range from level to vertical. Intervenors argued that the post-mining topography does not closely resemble the land prior to mining.

There are several conspicuous features on the post-mining topography map. Badlands are not reconstructed; the strata on which the badland topography has formed by erosion will be removed by mining. The post-mining topography map shows a regraded spoil pile about 100 feet high in the position of the boxcut spoils with slopes several hundred feet in length and slope angles of up to

3:1 (33 percent). This spoil pile apparently is outside of the mined-out area, but is not excess spoil. The permit application states that there is no excess spoil disposal at this mine, and the regulatory authority confirms that boxcut spoils were not considered to be out-of-pit disposal at this or any other mine at the state. There is also a depression in the position of the initial boxcut, which extends the length of the initial cut and is about 25 feet below the pre-mining ground surface. It apparently does not comply with the state requirment to eliminate closed depressions (20-102), but according to the regulatory authority does not disrupt surface drainage.

The state decision document does not address approximate original contour, the large spoil pile or the depression. The regulatory authority recently stated that some revisions should be made in the proposed post-mining topography. They are requiring a revision of the permit to reduce the height and slope length of the spoil pile and to minimize the occurrence of the closed depression. This issue is currently being negotiated between the state and the operator. Any change in the configuration of the boxcut spoil pile will affect the utilization of the coal resource because there is very little room within the 600 acre permit area to allow for modification of the mine plan.

3.13.6 Land Use. The pre-mining legal use of the site, according to the permit application, was limited grazing, and the proposed post-mining use was limited grazing. The pre-mining use of the land was established by grazing leases and by the presence of stockponds, corrals, etc. There was no zoning classification under local law. There was no mention in the permit application of the wilderness study area that surrounded the site on three sides.

Intervenors asserted that the major pre-mining uses of the land were for recreation, scenic values, and scientific purposes, and that these uses could not be restored, and the post-mining landscape would not be capable of supporting these uses. They also argued that the proposed use would not be compatible with the land use of the surrounding area. According to the regulatory authority, the land was state land and the public did not have the right of access; therefore the land did not have the capability to support recreational or similar uses. The regulatory authority also asserts that the reclaimed land will not be incompatible with the recreational use of the surrounding land after reclamation.

3.13.7 Reclamation Practice. The sandstone strata is currently being salvaged using loader trucks. Salvage operations are based on a highwall sampling program, and in the near future will be based on analysis of cuttings taken from rotary drilled blast holes, using air drilling to avoid contamination.

The mine operator is investigating the use of other materials such as scoria for substitute plant growth material. The materials being salvaged are clayey sandstones or siltstones, and salvage operations try to maximize use of the coarser textured materials with clay contents less than about 25 or 30 percent. The high sodium contents will have some affect on the physical characteristics of the spoil according to the operator.

The topdressing will be redressed in two lifts of 8 to 10 inches. The first lift will be disked into the underlying spoil to minimize the occurrence of a textural barrier, and the second lift will be redressed over it.

3.13.8 Research. A research plot has been established to evaluate the use of the sandstone as an alternative topdressing material. Several different treatments of topdressing thickness (0 to 18 inches), number of lifts, and disking are being investigated. The erodibility of the material on 3:1 slopes also is being observed.

4.0 ANALYSIS

Section 4.0 evaluates many aspects of soil and overburden management; the use of databases, baseline data collection and analytical techniques, reclamation techniques, models for predicting and evaluating reclamation success, bond release criteria and reclamation monitoring. It addresses the use of databases in the characterization of soil and overburden. Where the data are not used, possible explanations are given and where there are gaps and uncertainties in the available data, means of filling those gaps are suggested (section 4.1). The section also evaluates the methods of baseline data collection and analytical techniques used prior to mining to characterize soils and overburden, and the incorporation of the information into reclamation planning (section 4.2). It describes current techniques of soil and overburden management in reclamation (section 4.3), the methods used by the regulatory authority to evaluate proposed reclamation plans (section 4.4), and the techniques and criteria used to gauge the success of soil reconstruction, and the adequacy of the documentation for those techniques (section 4.5). The levels and kinds of uncertainties introduced by the assumptions, variables, and data which support the analytical techniques are identified and means of resolving those uncertainties are suggested. Where the data and techniques used prior to mining are found to have been inaccurate in predicting the effects on soils and the success of soil reconstruction, means of improving the accuracy are suggested.

This section addresses uncertainties. However, in one case study, soils and overburden are not problems at all. In others, problems have been more or less resolved and solutions that are sometimes compromises are being implemented; but there are areas of uncertainity and debate. The uncertainties are of a technical nature and most of the debate is a function of the four totally different perspectives on the problem, i.e., industry, regulatory, environmental and research. The author has tried to present all four perspectives.

4.1 Databases

4.1.1 Soil Databases. The SCS soil surveys used in the permit application process are of consistent National Cooperative Soil Survey standards and are either published or available from the SCS field offices (section 2.1.1). Because the regulatory authorities require detailed site-specific soil inventories, it is not necessary to obtain soil data from adjacent mines, even though it would be useful. Permit applications from adjacent mines could be a source of soil chemical data, but there are problems in quality (table 4.2-1) and the data are in fairly inaccessible formats. In addition, there is some sentiment among industry that it would be inappropriate for one company to use data from a neighbor's permit application. Only one application reviewed (case study F) referenced the soil inventories at adjacent mines.

The Wyoming regulatory authority has data base management systems available for compiling soil and overburden chemical data, and data on permit applications are currently being entered. Subjective judgement of the regulatory authority staff is being used to determine whether the data are of good enough quality to enter. Eventually, the system may allow the regulatory authority to access a large amount of permit application data.

4.1.2 Overburden Databases. Essentially no use is made of overburden data from sources other than onsite drilling. One permit application reviewed (case study L) mentioned some drilling results from an oil and gas well near the permit area. As in soils, the regulatory authorities require site-specific data, so no effort is made to use offsite data.

The USGS has a number of computer-accessible coal databases relevant to overburden baseline studies. None were referenced in the applications reviewed, possibly because site-specific drilling and sampling are required and the USGS databases do not include all the parameters required by the agencies.

Colorado State University devoted considerable effort to developing a soil and overburden database system for use by the mining industry, but the BLM research funding stopped before the project was operable, although demonstration projects were completed.

The Western Soil and Overburden Task Force, comprised of state and federal regulators, academia, private and public labs, and industry, is working on improving laboratory methods and quality assurance in soil and overburden analysis (section 4.2.3). This effort will improve the possibility of developing a database for soil and overburden information. Given the present problems with a number of overburden chemical analyses (section 4.2.3), and the lack of documented laboratory quality assurance procedures, it is unlikely that an overburden database system can be developed using the presently available data. As the analytical procedures improve and better data become available, an overburden geochemical database system might be possible.

An overburden geochemical database might be used to extrapolate from existing mines to new mining areas. We suggest that overburden samples should be classified according to a uniform lithologic system for the western coal fields (Ferm _et al_. 1985). A similar system is used in the southern Applachian coal fields (Ferm and Weisenfluh 1981) and the Kentucky regulatory authority requires that overburden cores taken for permitting be identified using the system. The system includes a rock type key with descriptions, color photos of core, and an identification number to be assigned to the common overburden rock types in the coal measures. Even in the fluvial deposits of the Powder River Basin, at least some geochemical characteristics (section 4.2.2) seem to be releated to some of the major stratigraphic zones and rock types. If geochemical values were assigned a lithologic identification number by a standard system, it would facilitate the establishment of an overburden data- base which in turn might improve our understanding of the geochemical, lithological, stratigraphic and depositional relationships of the coal basins.

4.2 Baseline Data Collection and Analytical Techniques

This section evaluates the problems in the characterization of soil and overburden for the parameters important to reclamation planning. In soils, the objective is to determine which materials will be salvaged for use. For overburden, the objective is to evaluate reclaimability and to identify acid- and toxic-forming materials. Compared to overburden, soil baseline studies are in good shape. Soils are at the surface and therefore easy to observe, and the science of soil characterization is well established.

4.2.1 Soil Inventory and Evaluation. Soils of the mine sites are mapped using the methods of the National Cooperative Soil Surveys (NCSS) (USDA 1951, 1975, 1983). These methods are used for all the SCS county surveys across the country. The pre-mine soil inventories are not subject to USDA review, so there is more variablility than would be allowed under NCSS.

One minor problem in the soil inventories reviewed is the lack of consistency in the description of the composition of map units. Map units are composed of one, two or in some cases three major soil components and one or two minor inclusions. The percentage of each major component and each inclusion comprising the map unit should be estimated. For example, a Decolney-Olney loam map unit might contain 60% Decolney, 30% Olney, and 10% Shingle. In many of the soil inventories reviewed, there was no site-specific estimate of the percentages of the inclusions or in some cases even the major components. This shortcoming would affect the accuracy of any volume calculation made from the inventory because these percentages should be used in the calculation of the volume of soil material available from the map unit (section 2.3.1)

Several soil scientists interviewed expressed the opinion that the National Cooperative Soil Survey System (NCSS) was not appropriate for mapping mine soils because of its emphasis on soil morphological characteristics not necessarily pertinent to soil use for reclamation. A more appropriate system might be developed, but the present regulatory system depends on the NCSS. In our opinion, the NCSS method has provided a higher level of quality in the soil studies compared to overburden studies, and it would be a mistake not to use it.

Laboratory methods for topsoil analyses are fairly reliable agricultural soil tests from standard sources such as the USDA Handbook 60, Diagnosis and Improvement of Saline and Alkaline Soils USDA (1969), and American Society of Agronomy, Methods of Soil Analysis (Page 1982). However, there are problems in preparation, analytical methods, and instrumental analysis. The Western Soil and Overburden Task Force recently conducted round-robin tests on standard soil samples; the results from eight different labs of one round are summarized in table 4.2-1. Severson and Fisher (1985) have compiled the results of a soil and overburden testing round-robin. Their data and the data on table 4.2-1 show that there is considerable variability among laboratories.

The criteria used to determine the suitability of a soil for use in reclamation are criticized by industry as being agriculturally biased (not applicable to range plants), arbitrary and simplistic. An example is the criteria for boron. Salt-tolerant desert shrubs may be more tolerant of boron

Table 4.2-1

RESULTS OF A ROUND-ROBIN SOILS TESTS

(Carlstrom and Harrington, 1984)

parameter	mean	standard deviation	sample size	coefficient of variability
pH	7.9	0.3	8	4%
Electrical conductivity	10.1	1.5	7	15%
Saturation percent	64.5	8.5	8	13%
Sodium adsorption ratio	22.6	4.1	8	18%
Exchangeable sodium percent	38.3	13.4	6	35%
Percent sand	25.2	8.5	8	34%
Percent silt	46.1	6.9	8	15%
Percent clay	28.8	11.0	8	38%
Percent organic matter	2.0	0.4	6	20%
Boron	1.2	0.5	7	42%
Selenium	0.13	0.11	5	85%

than the criterion reflects, yet the criterion is applied in most cases without much regard to the planned revegetation species. Organic matter is only a criterion for first lift material in North Dakota and indirectly in

Montana (based on first lift color). The other three states do not use it, yet it is a very important measure of soil quality.

This review found that in most cases the pre-mine soil inventories accurately determined soil volumes available over the permit area and were sufficient for planning and permitting purposes, but were not sufficiently accurate for actual soil salvage and calculating volumes in a one-year salvage area. Three soil scientists estimated the volumes of soil predicted to be available in the baseline soil survey were accurate to ± 6 percent, ± 10 percent, and ± 20 percent. One stated that over small areas (one-year salvage area) the baseline survey could be misleading, but over a number of years the errors averaged out. Another reported that a 1,000 acre area which the baseline survey indicated had 12 inches of topsoil actually had only 4 inches because of high salts in the subsoil not detected during the baseline sampling program. In most cases, the calculation of soil volumes in a one-year area and the actual salvage operations require a soil staking (and possibly sampling) program (section 2.3.5).

Actual amounts of soil salvaged are highly variable due to a number of factors. Table 4.2-2 shows the depths of salvage for a number of soil series from ten mines in the eastern Powder River Basin. The differences in salvage depths for the same series are remarkable. For example, the Bidman series ranges from 18 to 72 inches, the Stoneham series from 24 to 72 inches, the Ulm series from 12 to 72 inches, the Worf series from 4 to 18 inches, and the Wibaux series from 0 to 14 inches.

Soil salvage depths for a given series can vary among mines because there are chemical and physical variations in series between mines and equipment limitations to salvage. In addition, variations in test results could effect salvage depth; table 4.2-1 shows considerable differences between laboratory

Table 4.2-2
SOIL SALVAGE DEPTHS BY SERIES FOR TEN SURFACE COAL MINES IN THE EASTERN POWDER RIVER BASIN OF WYOMING

Series	Mine 1	Mine 2	Mine 3	Mine 4	Mine 5	Mine 6	Mine 7	Mine 8	Mine 9	Mine 10
Bidman	60	18	27	72	40	18	70	30	--	--
Cushman	48	30	30	36	30	30	30	24	23	35
Kim	60	60	--	72	60	60	70	24	60	--
Olney	60	60	60	60	50	60	70	30	--	--
Renohill	24	--	12	40	30	30	30	12	30	--
Samsil	6	6	4	6	12	6	—	--	0	3
Shingle	12	6	8	18	12	6	—	6	16	15
Stoneham	60	60	--	72	--	60	70	24	50	--
Ulm	60	--	28	72	50	15	70	12	60	--
Worf	12	--	--	18	12	15	15	--	4	—
Thedalund	—	30	18	30	30	30	30	18	18	--
Wibaux	14	6	4	0	12	6	6	—	15	14
Ft Collins	—	60	60	72	50	60	70	42	96	--
Maysdorf	--	--	58	72	50	--	70	42	60	--
Bidman	—	--	24	72	40	18	70	--	--	18
Briggsdale	—	--	28	36	30	30	30	30	--	17
Vona	—	60	--	72	--	60	90	30	60	--

results for the same material. For example, if the criteria for exchangeable sodium percent or boron were limiting at a mine, the recommended salvage depth could be quite different depending on the lab used. Another possible explanation for the differences shown on table 4.2-1 is that operators stripping the minimum amount are concerned with soil quality and operators stripping the maximum amount are concerned with soil quantity.

In the author's opinion, the differences in soil salvage depths shown on table 4.2-2 suggest there are uncertainties in the characterization and handling of the soil resources (see also section 4.3.1). The regulatory authority disagrees and states that the differences shown on the table reflect only physical constraints and equipment limitations, and that operators must salvage "all suitable topsoil or approved surface materials" or face enforcement action.

4.2.2 Overburden Drilling, Description and Sampling. The programs for overburden characterization are full of uncertainties. Opinions range from abandoning the entire process to requiring increasing amounts of data. The principal uncertainties are drilling intensities required to characterize the strata, laboratory analyses and the criteria for suitability, but there are a number of other considerations.

As described in section 2.2.4, the purpose of the overburden drilling programs is to determine reclamation potential, to identify deleterious strata, to predict whether these strata will affect revegetation (or the groundwater chemistry), and where they will occur on the recontoured surface.

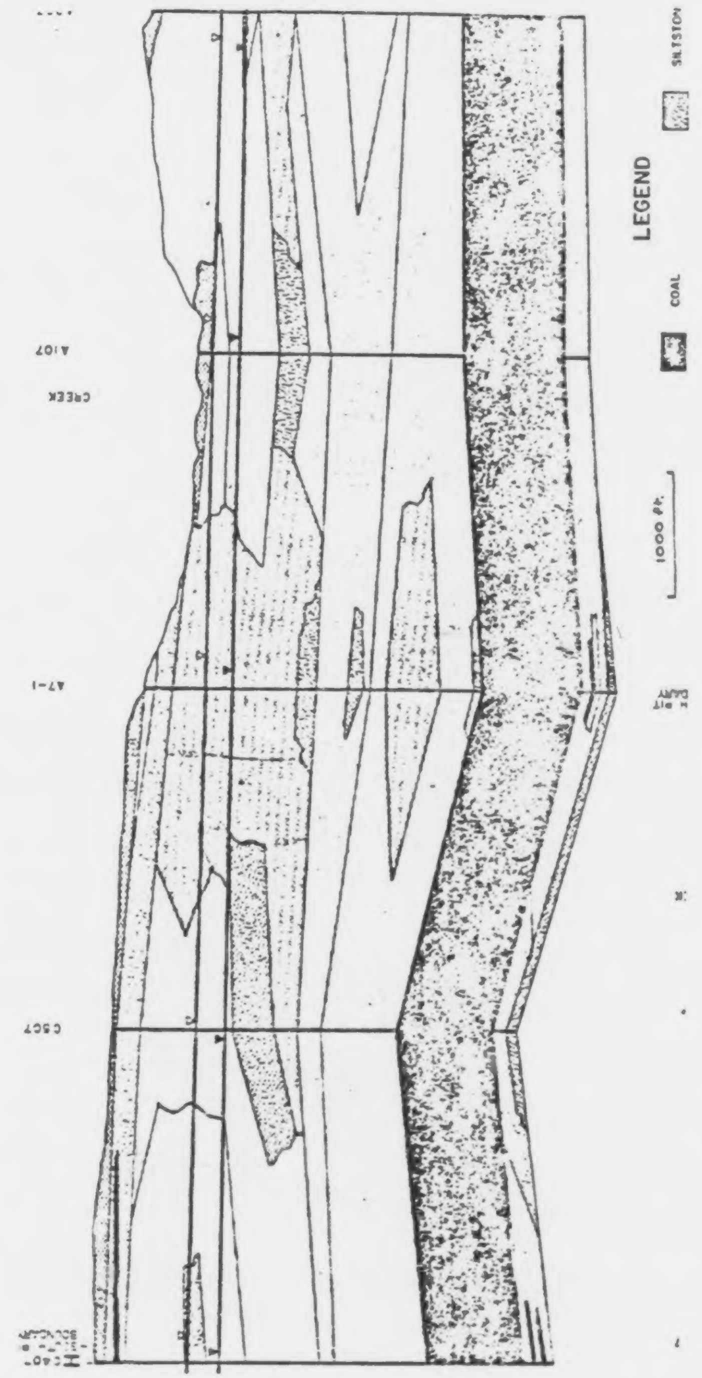
A study on the intensity of drill hole spacing necessary to characterize overburden (Dollhopf et al. 1981) found that an inordinately high intensity of drilling was required to predict the occurrence of deleterious strata accurately. At the mine investigated, a drill hole spacing of about 195 feet was required for 80 to 90 percent accuracy. The study suggested that most initial drilling programs would not delineate the location of deleterious strata, but would indicate those parameters most likely to be of concern. The data suggest that the accuracy of delineating unsuitable overburden zones at 1/4 mile (1320 feet) is not much better than at 1 mile (5280 feet). The minimum required drill hole intensity for the five states (table 2.7-2) ranges from one drill hole per 640 acres to one drill hole per 40 acres (representing spacings of 5280 feet and 1320 feet respectively). Sixteen times more holes are required in Montana than in Colorado. Common sense would suggest that 16 holes per section are a lot better than one, but Severson of the USGS (1984) points out that "...obviously, before much time and money are spent on a sampling program to characterize soil and overburden, there should be a reasonable certainty that the right data are collected (thus) common sense and intuition are not reliable indicators." The development of geostatistical models for drill hole intensity is an important research objective (Fransway 1983).

Lithologic descriptions in most of the permit applications reviewed are minimal. Figure 2.2-6 is an example of a typical geologic log for an overburden hole. Driller's logs often are used to fulfill the requirement for a description of the strata. A standardized system for lithologic description such as the rock-type key developed by Ferm et al. (1985) (section 4.1.2) would be an improvement and might facilitate stratigraphic correlations between drill holes.

In 11 of 12 cases reviewed for this study, the overburden stratigraphy of the mine pit area is not very well presented in the permit applications. This observation was true for all five states (but the applications reviewed may not be representative of more recent applications). In the 12 case studies reviewed, only one contained a fairly thorough, detailed presentation of overburden stratigraphy which included geophysical logs, cross sections and a highwall map. Figure 4.2-1 is an example of a stratigraphic cross section from that permit (reduced). In much of the coal fields of this study area the overburden strata are fluvial deposits that are lenticular and difficult or impossible to correlate. Several individuals in industry and the regulatory authorities state that the lenticular nature of the overburden makes any detailed stratigraphic analysis impractical and/or unnecessary.

This lenticularity makes determining the relationship of geochemistry to stratigraphy a difficult problem, especially in fluvial deposits. In the eastern Powder River Basin the consensus is that certain strata, such as the main carbonaceous shales and major sand bodies, may be stratigraphically correlative over significant distances and that some chemical parameters (such as acid potential and some trace metals) may be related to particular strata. There are other strata that are thin and discontinuous that can not be correlated and certain chemical parameters that do not seem to be related to any particular rock type or strata. In the author's opinion, more research needs to be done on the correlative strata and the related chemical parameters.

Sample contamination is another uncertainty in the overburden programs. Core and cutting samples have been contaminated by drilling fluids and pipe grease. Figure 4.2-2 shows a drill hole that was contaminated by lead at 20 foot intervals, the length of the drill stem. Case study C was required to double handle dragline interburden spoil thought to be high in molybdenum; a two-year study suggested possible contamination of some samples (Neuman and Munshower 1983). According to a staff member of the regulatory authority, the interburden strata is still considered to have elevated molybdenum levels but

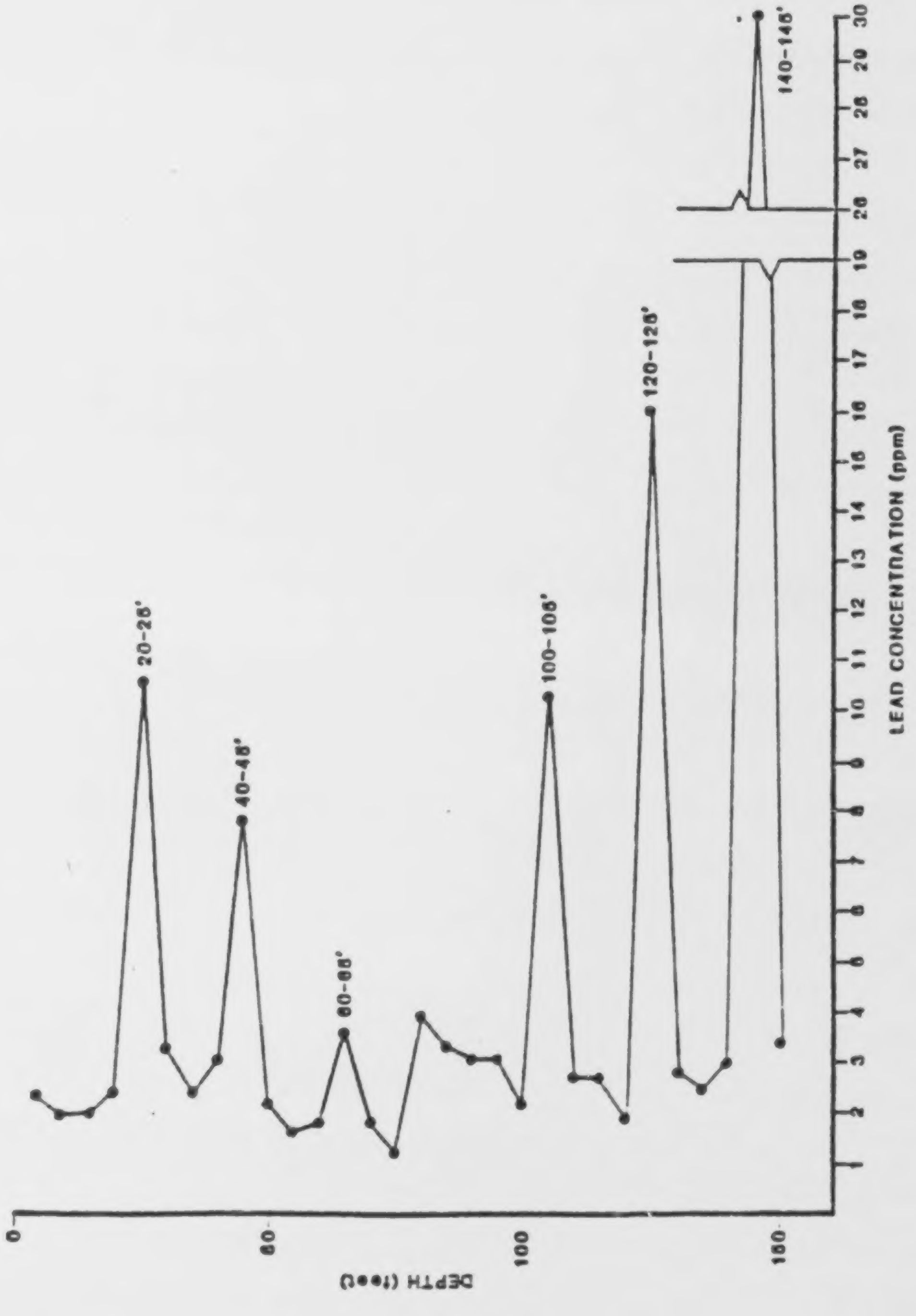


BOUNDARY
C507
A7-1
CREEK
A107
1000 Ft.
LEGEND
COAL
SILTSTON

Geologic Cross-Section showing stratigraphic correlations

James P. Walsh & Associates, Inc.

figure 4.2-1



Plot of Lead Concentration versus Depth

James P. Walsh & Associates, Inc.

figure 4.2-2

the contamination (if in fact the samples were contaminated) may have contributed to the impression that the problem was worse than it now appears to be. Other problems in sample handling such as oxidation have also affected analytical test results.

4.2.3 Acid-, Alkaline- and Toxic-Forming Overburden. The determination of acid-, alkaline- and toxic-forming strata is a subject of considerable debate in the industry. Some of the problem stems from the use of agricultural methods to characterize rock. There are major uncertainties involving the analytical methods used and the criteria on which suitability is based.

The acid potential of the rock is currently judged from the measurement of acid-base potential (ABP) as determined by a method devised by Smith (1974). The Wyoming DEQ presently specifies use of the induction furnace method. Acid potential is reported when the oxidation of sulfide minerals (principally pyrites) as measured by furnace induction, is larger than the neutralization potential of carbonates (principally lime) as measured by acid titration. These test methods undoubtedly do not measure precisely the reaction as it would occur on the ground (or in the groundwater). The analytical method may overestimate the contribution to acidity from organic sulfurs, may not accurately reflect the stoiciometry of the oxidation of the pyrite in the presence of oxidizing bacteria, and may not account for the reactivity of the lime. Some of the problems in analytical methods used for determining the acid-forming potential of carbonaceous shales in coal mine overburden are described by Boon, Smith and Lawton (undated). Dollhopf and Russell (1984) discuss the chemistry of the acid formation and associated reactions. For this paper, it is sufficient to state that more work must be done on developing methods of determining the acid potential for western spoil and overburden.

Acid production from spoil underlying redressed topsoil could probably adversely affect reclamation. One mine has a known acid problem with a sandy interburden and several mines are specially handling carbonaceous shales. One case study mine has pre-SMCRA spoils that are very strongly acidic. For the most part, western plant species have very low tolerance to acid soil conditions. For many years, acid formation was not considered to be a problem at western coal mines due to ubiquitous lime. Now four of the five state regulatory soil scientists report that there are mines in their states with some acid problem. Two staff scientists in the state regulatory authority stated that they expect acid spoil to be a long term reclamation problem at one case study mine.

The Wyoming DEQ now considers black carbonaceous shales and some pyritic sandstones to be potential acid-formers. The present position of the DEQ is that acid- and toxic-forming materials will be placed 4 feet below the reclaimed surface, above the post-mining water table, and out of the 100-year flood plain. Acid-forming materials found on the recontoured surface must be covered with 4 feet of suitable material or otherwise treated. Current guidelines specify that acid-base potential is to be measured on all overburden samples (WDEQ 1984).

The present position of the North Dakota regulatory authority is that the possibility of acid-formation is extremely limited due to the buffering capacity of the overburden and they do not routinely require a measurement of acid potential. Under the current (draft) guideline, the New Mexico regulatory authority (MMD 1984) specifies a measurement of acid-base potential only on strata that are non-calcareous (do not effervesce with dilute hydrochloric acid and consequently are low in neutralization potential).

Montana may require a measurement of acid base potential depending on the nature of the overburden (DSL 1983). Colorado guidelines (MLRD 1982) specify a determination of pyritic sulfur and sulfate sulfur but do not require a determination of lime. Consultations with the regulatory authority are suggested.

Many industry scientists are skeptical; several mentioned that the acid-base potential test overstates the acid production potential and has very poor reproducibility. Others reported that it can overstate neutralization potential as well. Montana, North Dakota, Colorado and New Mexico have not routinely required acid-base potential in overburden baseline studies. At this date, eastern Powder River Basin mines in Wyoming are running acid-base potential on all overburden and regraded spoil samples, and special handling known acid-formers and black carbonaceous shales. In the same coal measures in Montana, acid-base potential is not typically run and is not an issue.

Alkaline-forming materials typically have a high sodium adsorption ratio, a high pH (above 8.6) and often are clayey. Clayey and sodic materials at the surface will disperse and become impermeable to air and water and generally be unfavorable as a plant growth medium. Most of the sodic overburden materials at the case study mines are non-saline; that is, sodium is high relative to calcium and magnesium but total soluble salts are not high.

Clayey and sodic spoils make a poor plant growth medium. Some clayey and sodic pre-SMCRA spoils in North Dakota are still nearly bare. Early research indicated that just a few inches of topsoil dramatically improved reclamation results (table 2.4-1), but debate began concerning whether sodium from underlying spoil would migrate into overlying topsoil and adversely affect the physical properties of the reconstructed soil. Research was conducted on this subject at case study mine D and after several years, sodium migration did not appear to be a problem. However, the most recent data (Dollhopf et al 1985) shows that after 7 years, upward sodium migration had occurred and mathematical prediction of a worse case scenario indicated topsoil may be sodic (SAR $\geq$ 15) in 18-36 years. After 7 years the upward sodium migration had occurred on all of the test plots, including the control plot, in irrigated and non irrigated plots. Sodium migration was measured in some plots as far up as 46 cm (18 inches) into a total topsoil thickness of 70 cm (28 inches).

Case study mine L in the San Juan Basin of New Mexico was faced with a similar problem. There was some discussion as to whether clayey and sodic overburden was "toxic." Federal regulations define toxic as "...detrimental to...biota" - not a very specific definition - and at the time the regulations required 4 feet of suitable cover. Four feet of cover did not exist at this mine, but there could be no doubt that clayey spoil with an average sodium adsorption ratio of about 50 was "detrimental", but the state determined that sodium was not toxic to adapted desert species and an 18 inch topdressing of soil and regolith was approved. The regulatory authority required continued monitoring and research on the possibility of sodium migration, and recent work contends it is not a problem at this mine in a very low precipitation regime (Miyamoto 1983).

The method used to determine the sodium hazard can affect the volumes of material required to be handled. Case study mine I found that by using the state criteria for exchangeable sodium percent rather than sodium adsorption ratio, substantially more overburden was judged to be suitable and would not require special handling. When eight labs ran exchangeable sodium percent on one sample, the standard deviation was 35 percent of the mean (table 4.2-1). An uncertainty of this magnitude could have very large repercussions on spoil handling volumes.

Toxic overburden in the form of elevated trace metal content is an issue at three of the case study mines. Case study mine I has some boron problems; case study mine C has molybdenum problems; and case study mine L has selenium problems. Boron is often found at elevated levels in salty marine shales and can be quite toxic to plants; sensitive species will show symptoms of boron toxicity at a few parts per million. A soil and overburden criteria of 5 ppm is used in several of the states (table 2.3-1 and table 2.3-2). Case study mine I has boron levels above 5 ppm in a significant portion of the overburden and soil. The operator contends that the 5 ppm is arbitrary. Gardner saltbush is an important reclamation species at this mine and he contends that it is tolerant of much higher boron levels.

The molybdenum issue at case study mine C (section 3.3.3.) illustrates several problems common in overburden baseline characterization, namely inadequate data, sample contamination and arbitrary criteria. Elevated molybdenum levels relative to copper in plants can cause the disease molybdenosis in grazing animals. The mine was required to double handle dragline spoil for several years due to perceived elevated molybdenum levels in the interburden. The applicant's baseline data on the interburden was minimal, and there was almost no interpretation of the data. Apparently some of the samples may have been contaminated with a molybdenum-based pipe grease. The regulatory authority was forced to make a decision on very few data and required double handling. Several years later, after more baseline studies and some research had been conducted, it was concluded that many other factors would determine whether molybdenum would be a problem on the revegetated surface, and that it would be better resolved by monitoring. Consequently, a monitoring program was devised and the requirement for the double handling was discontinued.

Case study mine L has an ongoing problem with selenium in fly ash being disposed of in the mine pit. Selenium can cause the disease selenosis (or "blind staggers") in grazing animals. The Wyoming cattle industry has suffered significant cattle loss in certain areas where accumulator plants grow on selenium rich soils. At case study mine L, fly ash has been disposed of in the pit and covered with 4 feet of material for a number of years. Recently, elevated selenium levels were found to occur in the fly ash. The regulatory authority is now requiring 20 feet of cover, and the applicant maintains that there is not enough room in the pit for the fly ash and 20 feet of cover. The requirement is based on the concept of keeping the seleniferous materials below the rooting depth of the deepest rooted species most likely to occur. A complication in this scenario is that the laboratory method most often used for selenium has recently been found to be completely inadequate (Munshower undated; Boon, et al. undated). In the soil testing round-robin (section 4.2.1), selenium values ranged from 0.039 ppm to 0.17 ppm, a variability of 85 percent.

The placement in the post-mining groundwater table, of overburden materials that have the potential to form toxic leachates is a serious issue which could affect human health. The placement in the root zone of overburden that might affect plant quality (molybdenum, selenium) or revegetation success (boron) is not so serious a problem. Munshower (undated), director of the Montana Agricultural Research Center, believes that the regulatory programs for trace metal analyses of overburden materials are inadequate and ought to be discontinued. He states that the analytical procedures, toxicity levels, sampling intensity, soil reactions, etc. necessary to accomplish the concept of these programs do not exist. Published soil elemental suspect levels are not based upon even the presently available literature. In some cases the guidelines are overly restrictive, in others the indicated suspect concentration has never been recorded, and in some the concentration may or may not have any effect depending on other factors. Munshower suggests monitoring plant quality on the reclaimed surface and requiring corrective actions regardless of how expensive, if a problem develops. This is what is being done at case study C. However, as Hall (MMD 1984) points out, after a problem develops it may be impossible to correct as the resources may have been used up.

4.3 Reclamation Techniques

This section evaluates how the reclamation plans incorporate the soil and overburden physical and chemical properties as measured in the baseline studies, and how regulations affect the reclamation process.

4.3.1 Soil Handling. The topsoiling process ought to be an optimization process - too little soil and revegetation will be unsatisfactory; too much soil and lots of money is wasted. Soil handling is not optimized under the current regulatory framework and it is the second most expensive aspect of reclamation after recontouring. SMCRA intended that topsoil, defined as A and E horizons (originally the A horizon), be redressed over spoil and that subsoils be used only if the regulatory agency determines it to be necessary (30 CFR 816.22). The states in the study area with the execption of Colorado, have adopted the position that "all suitable soil" will be salvaged, including A, E, B, and C horizons, in many cases down to depths of 60 inches or more. "Suitable" is defined as soil that meets the criteria for pH, salinity, sodium adsorption ratio, texture, and possibly a few other parameters such as coarse fragments, lime, boron and selenium.

In most cases, soil is a better root zone material than spoil. Salvage of all suitable soil in many situations is appropriate, for example when undetected deleterious materials may occur in the spoil, where erosion is a concern, or where the moisture holding capacity of the spoil is limited. However, in our opinion, salvaging all suitable soil may not be appropriate in every case.

The surface layers of a soil contain microorganisms important for plant establishment, contain higher organic matter contents, and generally have better structure, aeration, lower resistance to root penetration, and infiltration capacity than subsoils. These favorable characteristics will be diluted by salvaging all suitable soil (including B and C horizons).

Where surface soils are low in organic matter and the soil nutrient content does not greatly exceed that of the spoil, a minimal thickness may be as effective as a thicker one (Hargis and Redente 1984). The moisture holding capacity of a soil low in organic matter may not be better than the spoil. Because the present baseline studies do not predict the characteristics (such as organic matter content or moisture holding capacity) of either the reclaimed soils or recontoured spoils, the justification for salvaging all suitable soil is lacking.

In some special cases (Halvorsen, Zimmerman and Melsted 1981), crop yields declined where soil thickness exceeded the optimum depth. When sandy loam topsoil was placed over moderately sodic clay loam spoil, yields tended to be lower on plots with 24 inches of topsoil than on plots with 12 inches of topsoil. The moisture holding capacity of the sandy loam topsoil was lower than the spoil, and yields declined apparently because the profile had higher water holding capacity when the root zone consisted of 12 inches of topsoil plus 12 inches of spoil instead of 24 inches of topsoil.

The available research (table 2.4-1) clearly shows that where spoil can function as a root zone, very little topsoil is required for optimum revegetation success (Barth and Martin 1982; Jensen, Dancer, and Duncan 1981; Bauer et al. 1978). The Colorado regulations [rule 4.06.2(3)] specifically state that subsoil "shall be segregated and replaced only if the Division determines that such material is necessary to ensure productivity consistent with the approved post-mining land use". The determination is generally site specific based on soil, overburden and climatic considerations.

In North Dakota, the regulation requiring all mines to salvage all suitable plant growth material was originally based on the assumption that all the overburden in the mining areas of the state were clayey and sodic. It is now known this is not the case, and the regulatory authority considered relaxing the requirement where spoil conditions were non-deleterious, but opposition from landowners prevented a change in the regulations.

There has been very little research on the depth of soil as a function of quality or depths of soil required over benign spoil. Much of the work has been on soil depths over problem spoils. Several industry scientists argue that the regulatory authorities have very little concern with the costs of their requirements. The applicant in case study E stated in the permit application that some C horizon materials should not be salvaged as they would decrease overall soil quality and were not significantly better than spoil as a rooting material. Analytical and greenhouse test results were reported to support the case, but the regulatory authority determined that the results of the tests were inconclusive and required by stipulation that these deep C horizons be salvaged and used.

North Dakota and Montana require soil salvage and redressing in two lifts. There is little research to support the assumption that two lifts are better than one, but the organic-rich topsoil should have better tilth and be more biologically active with microbes, seeds and rhizomes than the subsoil. Having topsoil at the surface of the reconstructed soil should achieve a stable and diverse soil-vegetation system more rapidly than one lift handling which mixes topsoil and subsoil.

Soil to be used as a plant growth medium is best preserved if it is direct-hauled, transferred directly from its native site to recontoured subsoil or overburden without stockpiling (Hargis and Redente 1984). Direct-haul topsoiling could conceiveably outweigh other considerations of soil quality or thickness. Direct-haul seems to provide for better rangeland plant diversity than stockpiled soil. Data on direct-haul soils are recently becoming available. Research by Argonne National Labs at case study mine I found four times the vegetation diversity on direct-haul soil relative to stockpiled soil (Jastrow, in press).

Existing regulations discourage direct-haul. For example, the requirement for approximate uniform thickness restricts direct-haul because direct-haul does not have the flexibility for redressing thickness inherent in the stockpiling system. Under direct-haul, redressed soil thickness would vary as the mine moved through areas of varying soil thickness. The requirement for saving all suitable soil, without a requirement for two lifts, makes the direct-haul method less effective. The biologic component of the surface layers that produces the beneficial effects of direct-haul is compromised by the requirement to salvage A, E, B, and C horizons.

For the re-establishment of rangeland, two lift direct-haul might be the best method of topsoil handling. A number of case study mines are using this system. At case study mine I, in one of the harshest sites of the five state region, the regulatory authority reports very encouraging revegetation results using the two lift direct-haul method. Direct-haul topsoiling is working so well and giving such good plant diversity at one mine in northwestern Colorado that the operator is proposing to eliminate seeding.

The requirement for approximate uniform topsoil thickness consistent with the proposed land use (30 CFR 816.22) is counter-productive in many ways. It directly conflicts with another regulation that requires the establishment of a diverse plant community. One operator suggested that redressed soil should be thicker on ridges and thinner in swales; the landscape would be designed to forestall the effects of soil erosion on ridges. Another suggested the opposite in the desert, where topsoil is limited and vegetation density is extremely low. Putting a very thin layer of topsoil on uplands and using most of the soil in the swales would produce deep soil profiles capable of storing moisture from run-on and supporting better vegetation cover. In the desert, a uniform thickness would result in soils unnecessarily deep on the uplands and too thin in the swales. In North Dakota, researchers have hypothesized that landscape position may be more important in dryland wheat production on reclaimed lands than soil thickness. It is possible that thinner soils could be placed in concave positions which support higher production regardless of soil thickness, and that thicker soils could be redressed on convex surfaces to maximize moisture holding capacity. The productivity of the entire area might be greater with this system than with uniform thickness. A number of individuals and organizations interviewed in this study including the Montana Coal Council, the North Dakota Agricultural Research Center, and several industry soil scientists argued against this regulation.

In fact, uniform topsoil thickness is being interpreted by the regulatory authorities to allow non-uniform thickness. Several case study mines had non-uniform thickness. Case study L had 8 inches of topsoil over coarse textured spoil and 18 inches elsewhere, even though the proposed land use for both areas was grazing. Case study mine C is not using uniform thickness where soils are being direct-hauled. Case study G is not using uniform thickness because of the long haulage distances that would be necessary to even out differences that occur naturally over the site. In the author's opinion, this represents considerable regulatory flexibility in the face of an often counter-productive regulation.

The regulatory authority must keep track of soil salvage and redressing volumes at the mines to assure compliance with the mine permit. Soil volume accounting, sometimes referred to as a soil budget, is a method that can be used to monitor soil volumes. The operator at case study mine C uses a soil volume accounting on an annual basis. The operator reassesses stripping depths for the years ahead based on current salvage, the volume in stockpiles, the volumes remaining to be salvaged, the remaining area to be redressed and the average depth of soil to be replaced. The operator expressed the opinion that it is a useful tool for the agency and the company.

All five states require information on soil volumes each year but the data required and use of the data varies. The Wyoming DEQ probably carries the process the furthest of the five states. They require all mines to report on an annual basis the volume in soil stockpiles, the volume salvaged during the report period and where it went (i.e. new pile, existing pile or redressing), volumes replaced on reclaimed land and where it came from (i.e. stockpile or salvage). That information is used to evaluate the volumes of soil being salvaged to date as compared to the permit requirement.

The New Mexico regulatory authority has not required a similar volume accounting but is now requiring it on an annual basis from mines where soil volumes are marginal, and they are considering making it a requirement in their annual reports for all mines. North Dakota mines have an abundance of soil and there is no annual volume accounting requirement. They receive annual updates on soil volumes in stockpiles and could calculate redressing thickness if a shortages appeared likely. Montana and Colorado have required annual volume accounting from a couple of mines but do not routinely require it.

It has been suggested that annual soil volume accounting might be a reasonable requirement for all mines. Environmental groups have criticized the enforcement of soil salvage (Johnson and Hildebrant 1984). According to staff members of the regulatory authorities it is a reasonable requirement for mines where soil volumes are marginal and at some mines during the final years of mining where shortages of soil could be critical. If non-uniform thickness is permitted for soil reconstruction, the regulatory authorities might need to require annual soil volume balances to determine the adequacy of soil handling because redressed soil thickness would no longer be a sufficient measure. However, there is no consensus that annual soil volume accounting would be a necessary requirement for all mines.

4.3.2 Overburden Handling. Special handling, recontoured spoil sampling, and 4 feet of cover, burial or treatment are sometimes required where deleterious strata occur in the overburden or spoil (section 2.3.4 and 2.3.5). There are uncertainties involved at each step of the process.

Several case study mines have been required to special handle materials; mines E and F are truck and shovel operations in the Powder River Basin of Wyoming and both special handle, mine C was required to double handle dragline spoil, and mines G and I are draglines that would use modified swings if it were found to be necessary. Case study M is special handling an overburden stratum for use as a topsoil alternative.

It is interesting to note the mines that are not required to special handle. Mines B and L are assumed to have all deleterious strata. Mine H has acid-forming strata but is a dragline operation and is not required to special handle. Mines A and J have benign overburden. According to some Wyoming truck and shovel operators, they are more likely to be required to special handle material than competitors with draglines because the flexibility of their equipment makes it easier to do so.

Recontoured spoil sampling programs are the norm in Wyoming and Montana, but not in the other three states in the study area. Samples are collected on a routine basis from a grid pattern or from composite samples. Case study mine C has an interesting system for spoil sampling. Recontoured spoils are tested for molybdenum: if an area has more than 6 ppm molybdenum it is covered; if it is between 2 and 6 ppm, vegetation transects will be set up on the revegetated surface and the vegetation monitored for molybdenum; if it becomes a problem, the area will be reconstructed.

The statistical validity of most of the recontoured spoil sampling programs has not been established. The size (geostatistical variation) of the unsuitable spoil areas must be known before the acceptable sample intensity can be determined (Klusman 1980). The grid spacings of the recontoured spoil sampling programs in Wyoming range from 200 to 625 feet and average 400 feet. Several operators report that the unsuitable areas are small relative to the grid pattern. One mine operator (case study I) reported that on the first 60 acres sampled on a 500-foot grid they found two unsuitable samples, but at 50 feet out from those spots the samples were suitable. Another (case study F) reported that sampling in concentric circles around an unsuitable spot could not delineate unsuitable areas.

The Wyoming DEQ (Naftz 1984) has recently begun to investigate the statistical basis for the required sampling densities (both vertical and horizontal) on regraded spoils to insure the adequate delineation of unsuitable material. A nested hierarchial analysis of variance was applied to regraded spoil data from one mine. It was concluded that to adequately distinguish between 6 acre parcels at the 95% confidence level, approximately three to five samples were needed to describe their chemical differences for the parameters pH, salinity and saturation percent (two samples at the 80% confidence level). Six acre parcels could not be distinguished from one another when analyzing for acid-base potential. It was suggested that a similar analysis was required for the parameters of concern at each mine in order to determine adequate sample densities. In the author's opinion, statistical analysis of the sampling densities necessary to characterize the regraded spoil for the specific parameters of concern should be conducted at all mines with recontoured spoil sampling programs and the programs modified accordingly or discontinued. The existing programs may be giving a false sense of confidence that deleterious materials on the recontoured surface will be detected.

The requirement for 4 feet of cover over deleterious materials is a subject of debate. Industry generally favors performance standards over design standards, for example "adequate" cover (based on spoil and soil chemistry, physical properties, vegetation, climate etc.) rather than "4 feet". Federal regulations originally specified 4 feet of suitable cover but this has recently been revised to "adequately covered " (30 CFR 816.102). Wyoming still requires 4 feet, Montana requires 8 feet, and North Dakota requires up to 5 feet (a minimum of 4 feet) over all spoil whether it is deleterious or not. New Mexico requires the salvage of all suitable topdressing material but a number of mines have been permitted with less than 4 feet. At case study L in New Mexico, 18 inches of suitable topdressing over clayey and sodic spoil was permitted because it was the all of the suitable topdressing available.

Where 4 feet of cover is unavailable, treatment of acid-forming spoils might be necessary. Liming may not be an adequate long-term solution to the problem of acid spoils; Boon (undated) reports that liming may only be a temporary solution.

4.3.3 Land Use and Topography. The analysis of reclamation techniques indicated several topics, peripheral to soils and overburden, that are areas of uncertainty. They are land capability, land use, and approximate original contour. They are discussed here because land capability and use are a direct function of soil reconstruction and approximate original contour affects overburden handling.

Federal regulations require that "all disturbed areas shall be restored...to conditions that are capable of supporting the uses they were capable of supporting before any mining or higher or better uses" (30 CFR 816.133). The states vary considerably in their treatment of post-mining land use (section 5.3), but the analysis of land capability and use in the permitting process has was fairly cursory in the cases reviewed.

The word "capable" in 30 CFR 816.133 suggests the use of the USDA Land Capability Classification System. This system evaluates lands based on soils, climate and topography, and ranks them from class I (lands most suitable for agriculture) to class VIII (lands suitable only for watershed and wildlife habitat). Figure 4.3-1 shows the system for rating soils, topography and climate to determine land capability in Colorado (Dansdill and King 1978).

COLORADO GUIDE FOR PLACEMENT OF SOILS INTO CAPABILITY CLASSES

Both climatic limitations and soil property limitations are used. Limits are imposed by each and the capability class assigned a soil cannot be less restrictive than the class imposed by either. Soils having two or more severe or very severe limitations are usually dropped at least one class.

Soil Properties Limitations

Land Capability Class	Minimum Soil Rooting Depth (inches)	Surface Soil: Textural Classes Permitted	Surface Soil: Maximum Coarse Frags Permitted (Percent) <3"	Surface Soil: Maximum Coarse Frags Permitted (Percent) >3"	Maximum Slope Percentage	Minimum Permeability (Inches/hr) Within Top 20"	Top 40"	Top 60"	Minimum Available Water Capacity (inches) Within Top 12"	Top 40"	Top 60"	Minimum Drainage Class and Growing Season Watertable Depth (feet)	Maximum Flood Hazard (Mar-Sept)	Maximum Salinity[1] (mmhos/cm) Within Top 20"	Top 40"	Maximum Erosion Hazard by Water[2] (KaS^2aR)	Maximum Erosion Hazard by Wind[3] IaC
I	60	CL, SiCL, SCL, L, SiL, SL, VFSL, FSL, CoSL	15	0.01	1	0.2	0.2	0.06	1.5	6.0	9.0	Moderately Well 3.5	None	2	2	Slight 1	40
II	40	Above plus C, SiC, LVFS, LFS, LS, LCoS	35	0.1	3	0.2	0.06	0	1.0	3.0	6.0	Somewhat poorly 1.5	Occasional	2	4	Moderate 2	60
III	20	Same as Above	35	1.0	6	0.06	0	0	0.75	4.0	4.5	Poorly 1.0	Occasional	6[3]	8	High 5	125
IV	20	Same as Above plus Sand	65	3.0	12[4]	<0.06	0	0	0.60	3.0	3.0	Very Poorly 0.5	Occasional	8[3]	16	Very High 10	200
V	60	Any	65	15	5	0.2	0.2	0	1.5	6.0	6.0	Any	Occasional	2	4	Slight 2	60
VI	10	Any	65	15	25	0.06	0	0	0.5	2.0	2.0	Any	Frequent	8	16	Any	Any
VII	4	Any	95	95	65	<0.01	0	0	0.2	0.5	0.5	Any	Frequent	16	Any	Any	Any
VIII	0	Any	100	100	Any	0	0	0	0	0	0	Any	Frequent	Any	Any	Any	Any

[1] Where the exchangeable sodium percent exceeds 15% in the surface 10 inches, class is VII; if sodium percentage is low in the surface, but above 15% in the 10 to 30 inch layer, class maximum of IV.

[2] Water erosion hazard calculated using formula $E_w = KaS^2aR$ where E_w = erosion hazard, K = soil erodibility factor, S = slope percent and R = rainfall intensity factor - 0.7 in eastern Colorado and 0.4 in western Colorado.

[3] Wind erosion hazard calculated using formula Eb = IaC where Eb = Soil blowing hazard, I = Soil erodibility, C = Climatic factor for county.

[4] Maximum 3 percent in area of PE = 19 to 25.

[5] Maximum LCC VI if PE is less than 44.

10/77
[illegible]

Climatic Limitations

Moisture (PE Index)	Frost Free Growing Season Days: >140	120-140	100-120	70-100	<70
64 or >64	I	II	III	IV	V
38 to 64	II	II	III	IV	VI
25 to 38	III	III	III	IV	VI
19 to 25	IV	IV	IV	IV	VI
13 to 19	VI	VI	VI	VI	VI
<13	VII	VII	VII	VII	VII

Colorado Guide for Placement of
Soils into Capability Classes

James P. Walsh & Associates, Inc.

figure 4.3-1

The criteria used for evaluating land capability are minimum soil rooting depth, textural classes and coarse fragments on the surface, slope, permeability, available water holding capacity, drainage, flood hazard, salinity, erosion hazard, moisture index, and length of growing season. All of these parameters could be predicted for the reclaimed soil from the baseline studies or measured on the reclaimed surface. The use of this system could assist in the development of predictive soil reconstruction models (section 4.4.1), and be used to evaluate soil/spoil reconstruction success. No comparable models were used in any of the permits reviewed.

The US Forest Service (Rounsaville 1977) developed a system for predicting potential land capability classes on reclaimed surfaces. The acreages in each capability class in the pre-mine condition were compared to the predicted acreages in the post-mining condition to determine if the land capability would be maintained. Schafer (1982) has also mapped the land capability classes of reclaimed land in order to compare pre-mining and post-mining land capability. A more rigorous treatment of land capability than is presently being used in baseline studies may assure that land potentials are being protected.

At case study mine F, about 155 acres of land had at one time been used for dryland wheat. An area of similar size was reconstructed with a minimum of 24 inches of topsoil and favorable slopes in order to preserve that capability, even though dryland wheat farming in the area is not considered viable. In this case land capability was preserved.

The federal regulations require that disturbed areas be backfilled and graded to achieve "the approximate original contour" (30 CFR 816.102). The wording probably was intended to prevent large discrepancies between pre-mining and post-mining topography, but it suggests that geomorphology was not considered when the regulation was written. The post-mining topography should be consistent with the hydrologic characteristics of the reconstructed soils, the revegetation communities, the reconstructed drainage systems, and the proposed post-mining land use, and should be compatible with the geomorphology of the contiguous areas to the extent possible. The approximate original contour may be inappropriate for the reconstructed landscape. Hogback ridges are a simple example of a pre-mining topography that would be counter-productive to re-create on a reclaimed surface because they are supported by resistant strata that are removed by mining.

One regulatory agency suggested that in such cases variances could be requested. Researchers in North Dakota have suggested that requiring restoration of pre-mine contours is detrimental to the best reclamation in North Dakota (personal communication, Doll 1985). Industry generally considers the requirement overly restrictive. Environmentalists consider the requirement to achieve approximate original contour to be an important environmental protection of the law. The four different views reflect the different perspectives on the problem.

4.4 Models for Predicting Reclamation Success

When a permit application is submitted with baseline data, a mine plan and a reclamation plan, the regulatory authority must make a finding of reclaimability (section 2.4). Fisher and Judy (1984) call~~s~~ this the most comprehensive and difficult aspect of the entire regulatory program. They suggest the development of qualitative predictive models and propose that more research is needed to develop and test the models and make them more quantitative. The regulatory authorities presently use informal models; they essentially evaluate compliance, the spoil quality and soil thickness, the revegetation plan and revegetation success at similar mines. Some individuals interviewed for this study in the regulatory authority (and in industry) do not agree that quantitative models are an important research objective.

4.4.1 Available Quantitative Models. There are few quantitative models for predicting the probability of reclamation success. The USGS (1980) developed a climatic model for the appraisal of the rehabilitation potential of strippable coal lands in the Green River Basin. The three climatic elements found most useful in evaluating rehabilitation potential were growing season length, irrigation water requirement and mean monthly precipitation. The irrigation water requirement was used as a measure of water deficiency.

Packer et al. (1982) developed a quantitative model of reclamation success that evaluated production and cover as a function of a number of variables. The research showed that precipitation, growing season, spoil potassium, sodium and pH, seven revegetation treatments, and age accounted for much of the variance in production and cover. Their field work on this model was conducted in 1976, and the results probably are not relevant to post-SMCRA reclamation techniques.

Doll, Merrill and Halvorsen (1984) proposed a system for evaluating reclamation success based on a productivity index of the reconstructed soil. Current productivity indexes for natural soils are based on the correlation of field classification with laboratory measurements of chemical, physical and mineralogical properties and with landscape position. Snarski et al. (1981) has conducted some experiments designed to test the ability to predict the chemical and physical properties of soil mixtures for mine reclamation planning. Similar indices could be developed to predict the productive capacity of reclaimed soils in the permitting process and used to judge the success of soil reconstruction after mining (section 4.5.1). Doll, Merrill and Halvorsen (1984) suggest that "refining and adapting these productivity indexes for use in reclamation will facilitate the most effective use of available soil and spoil materials for restoring optimum post-mine productivity."

4.4.2 Uncertainties. There are uncertainties in the reclamation of western coal lands that relate to soils and overburden. The staff scientists at two state regulatory agencies expressed the opinion that there will be long range reclamation problems at three case study mines. A USGS researcher expressed a similar concern about a fourth case study mine. In all four cases, the uncertainites relate to overburden chemistry and interactions with the soil cover.

In the opinion of some workers (Fisher and Judy 1984), if the uncertainties are to be resolved in the future, better quantitative models need to be developed to predict reclamation success. The models will depend on high quality baseline characterization of the soils and overburden and can be refined over time as more soil and overburden data become available and revegetation success is monitored.

4.5 Criteria for Evaluation of Reclamation Success and Bond Release

4.5.1 Reconstructed Soils. The criteria for evaluating reclamation success for soils are extremely limited. In most cases, soil reconstruction is considered to be a success if it is as thick as predicted in the baseline study and the lifts (if required) are in the correct order. If the permit has any special stipulations regarding soils, these also are evaluated. Erosion must not exceed pre-mine levels or contribute additional suspended solids to stream flow outside the permit area (30 CFR 816.41).

Redressed soil thickness is used as a criterion for reclamation success to facilitate inspection. At mines where non-uniform soil thickness is permitted, the regulatory authority might need to require annual topsoil volume balances to determine the adequacy of topsoil handling.

Several permit applications reviewed had stipulations regarding soil monitoring for salinity, sodium adsorption ratio, pH, etc. In most cases, there were no criteria stating the value considered to be a problem or what would be done should a problem occur. The exception is the stipulation regarding molybdenum at case study C (section 3.3.6). There is a stipulation to monitor sodium migration at case study mine L indicating some doubt on the part of the regulatory authority as to whether 18 inches of cover is adequate. It is not clear what would be done if a problem should develop.

Only two case study mines have quantitative measurements of erosion from reclaimed surfaces on a routine basis (there are other research plots not designed for bond release). Case study mine D has set up runoff plots on native and reclaimed areas and case study mine F has a small watershed study. Case study mine J has semi-quantitative monitoring. Montana has developed a draft guideline for evaluating erosion of reclaimed surfaces for the purpose of bond release. It recommends two years of sediment yield data of unobstructed stream flow on the highest order stream in the drainage basin, collected concurrently with the vegetation data (DSL 1982). The other states in the study area have no such guideline and the Montana draft guideline is not being used at this time.

David Stiller and Associates (1983) evaluated a number of techniques for measuring erosion and sediment yield from reclaimed surfaces for the purposes of bond release. Stiller suggested that satisfactory post-mining vegetation cover be accepted as prima faci evidence of satisfactory erosion control. If this is not acceptable, comparative rainfall simulator analyses of range sites representing reclaimed and undisturbed surfaces were recommended. It was suggested that sediment yield data be collected through periodic bathymetric surveys of sediment ponds on reclaimed sites and compared to sediment yield data collected from stockponds and irrigation structures in undisturbed drainage basins.

4.5.2 Recontoured Overburden. The adequacy of the overburden handling and reconstruction of the root zone are evaluated as criteria of reclamation success. The post-mining topography map is used to determine if overburden volumes have been handled appropriately. Industry does not agree with this criterion. It is the position of the Montana Coal Council (1984), for example, that the post-mining topography map should be considered an affirmative demonstration that spoil volumes are adequate and not a depiction of exactly what a given area will become a number of years in the future. The opinion is that operators should be held to performance standards (erosion, slope angles, drainage, etc.) but not a map.

The chemical quality of the recontoured spoil is a measure of reclamation success for seven mines in the study (five in Wyoming and two in Montana. For these mines, the regraded spoil sampling programs determine if the spoil meets the accepted criteria. In addition to all the uncertainties involved in sampling, analyzing and interpreting the spoil data (section 4.3.2), there are other criteria that should be evaluated but are not, such as whether the spoil is functioning as a root zone for re-established plant communities where intended.

A few mines are evaluating subsidence as a spoil handling criterion, which is a fairly straightforward process (section 2.3.4).

4.6 Soil and Spoil Monitoring

Reconstructed soil/spoil profiles are not being monitored on a routine long-term basis on normal reclaimed landscapes. The monitoring that is being done addresses specific concerns of the regulatory authorities at specific mines. In typical situations, the reconstructed soil/spoil profiles will not be examined unless vegetation indicates a problem. The list of monitoring programs at the 13 case study mines is as follows: case study C - molybdenum; case study D - erosion, subsidence, and sodium; case study F - erosion; case study I - effects of irrigation water; case study J - erosion; case study L - sodium. Hargis and Redente (1984) present the case for monitoring:

> The state of the art in soil and overburden management on disturbed land in the west is based largely on the response of plant cover and biomass to the management practice employed. With current trends in research, in another five years the state of the art will be based on the response of essential ecosystem processes, such as mycorrhizal infection, nutrient cycling, and soil-water dynamics to disturbance and management...(one) of these processes is nutrient cycling. Before we can say that we understand the effects of reclamation treatments we need to monitor revegetation response long enough (5 to 10 years) to see how well the system sustains vegetation production. As a basis for this we need to monitor specific nutrient cycling parameters such as mineralization and immobilization to determine how well the system functions.

SMCRA gives the states authority to require monitoring, but several individuals in the regulatory authority expressed the opinion that the kind of monitoring envisioned by Redente, such as nutrient cycling and other soil functions, may be important research considerations (section 5.4.2) but are not supported by the language of SMCRA. Futhermore, these individuals are of the opinion that revegetation success will be an adequate indicator of the soil/spoil reconstruction.

There are others (including the author) of the opinion that the parameters measured to determine revegetation success, will not be sufficient to judge the success of the soil/spoil reconstruction in some situations. For example, it has been suggested that in certain situations, acid-formation could overcome the buffering capacity of the reconstructed soil at some time beyond the 10 year bond release period. A reconstructed soil could support vegetation for a period of time (beyond bond release) and then fail due to unsustainable erosion rates. Land owners involved in this study have expressed concern that vegetation quality might decline over time on reconstructed soils. Research on sodium migration at case study mine D indicates that upward diffusion of sodium from underlying spoils can take place at a very slow rate; the process can be so slow that high SAR levels ($\geq$15) may not be present for one to several decades (if ever), depending on the soils physical and mineralogical properties (Dollhopf et al 1985). These uncertainties suggest that there is an important need for research on soil and overburden monitoring (Doll, Merrill and Halvorsen 1984; RRAC and NDPSC 1984; Hargis and Redente 1984; National Research Council 1981).

5.0 ISSUES

5.1 Innovation, Ecologic Variability and Regulatory Flexibility

5.1.1 The Need for Innovation. The need for innovation is an important issue. Reclamation in the west is a new science and it is critical that it be allowed to improve. Whether or not there is sufficient flexibility under the existing regulatory system to allow for the evolution of the science is a matter of perspective; many industry scientists believe there is not; environmentalists and regulators contend there is.

The ecologic, pedologic and geologic variability between the sites in this study is remarkable. Case study A is gently rolling cropland with chemically benign glacial till and deep, rich Mollisols. Across the river, case study B has clayey, sodic shales. Case study C has a vertical sandstone highwall that conforms with approximate original contour, and chemically benign topsoil, while case study D has a sodium problem and shallow aridic soils. Case studies E and F, only a few miles apart, are typical eastern Powder River Basin mines and are more similar than any other mines in the study. Case study G, in the same basin, has a problem with a pyritic sandstone. Case study H has steeply dipping multiple units. Case study I, not far away, has boron problems. Case study J is in the mountain shrub communities of northwestern Colorado, and the soils are thick Mollisols. Case study K has a few inches of soil that support a pinon-juniper community. Case study L has clayey, sodic overburden and 18 inches of topdressing while case study M, about an hour's drive to the south, has no soil at all.

There is a continuing debate between industry on one side and the regulatory authority and environmentalists on the other, on the need for design standards versus performance standards and their affect on innovation.

Design standards may discourage innovation and may not take into account the tremendous variability among sites. Every operator interviewed expressed a preference for performance standards rather than design standards. From their perspective, the movement away from design standards as the result of recent judicial decisions is a welcome trend. They regard performance standards as the most economic and effective approach to assure successful reclamation. For example, the requirement to apply uniform topsoil thickness may be counter-productive (section 4.3.1). The requirement in several states to salvage all suitable topsoil may not be optimizing the use of the resource (section 4.3.1). The requirement to eliminate closed depressions in the desert southwest and in the Powder River Basin may be eliminating opportunities for wildlife habitat. The requirement to obtain approximate original contour may be counter-productive to the best reclamation (section 4.3.3). However, in the author's opinion, there is some doubt that performance standards can be enforced because there are so few criteria for evaluating soil/spoil reconstruction and very little monitoring of reconstructed soil/spoil profiles.

During this study, OSM was repeatedly criticized by industry (and by a few state regulatory agencies) for being too inflexible (although this study did find a number of cases of regulatory flexibility on the part of OSM (section 3.2.4, 3.3.5 and 4.3.1). Naturally, the state regulatory agencies argued for more state control. One clearly stated his opinion as follows:

> "OSM tries too much to standardize...a basic federal approach...they overlook the states' biological diversities... OSM is looking at a guideline for overburden sample analysis...it will be a disaster if OSM follows this line of reasoning... if OSM is trying to regulate the guidelines on a uniform basis so that they avoid allowing a practice in one place and disallowing it in another, then they are mixing politics with ecology."

On the other hand, OSM may be trying to regulate the guidelines on a uniform basis in order to administer a large program with the financial resources allotted to them.

The use of guidelines as opposed to rules may also affect regulatory flexibility and innovation. Some states are reluctant to have guidelines; the North Dakota Public Service Commission is not allowed to have guidelines. Soil use criteria that they would like to establish must go through the public hearing process and be incorporated into the rules. Instead, the regulatory authority uses memoranda to explain and clarify the rules. Colorado does not have published guidelines for soils but they do have guidelines for overburden. Several operators expressed the opinion that in Wyoming, guidelines tend to be interpreted too rigidly, even though each guideline states that "this document is a guideline only. It's contents are not to be interpreted by applicants or DEQ staff as mandatory." On the other hand, the guidelines of the Wyoming DEQ have been undergoing constant revisions for years (another example of regulatory flexibility). This creates problems for the industry, but does allow for evolution essential to the growth of the science of reclamation.

Regulatory flexibility is affected where requirements that belong in guidelines are written into the regulations. For example, New Mexico has the requirement for 20 trace metal analyses for overburden samples in the regulations. One case study reviewed had 40 pages of overburden trace metal analyses without a single sentence of evaluation of the data. This regulation is now being routinely waived and is slated to be rewritten, but the other states have already dropped most of these trace metals from their guidelines.

Several environmentalists involved in this study do not agree with the opinion that innovation needs to be encouraged. Their principal concern is enforcement of the law (Johnson and Hildebrant 1984) and they conclude from these case studies that sufficient flexibility exists in the regulatory system to allow for improvement in reclamation technology. This study found some very good examples of regulatory flexibility. For example, the requirement for approximate uniform topsoil thickness (a counter-productive requirement in many cases) is being interpreted to allow non-uniform topsoil replacement where it is appropriate (section 4.3.1).

5.1.2 Innovative Practices. Table 5.1-1 is a list of innovative practices that involve soil and overburden at the case study mines. Some of these practices are more innovative than others, some may or may not be effective, and some have not been approved by the regulatory authorities.

None of these practices were permitted under the experimental practice provision of the regulations. In fact, Montana is not allowed to permit practices considered experimental. The "bluff extension" at case study mine C was permitted as an alternative reclamation plan. All of the other practices were permitted under the normal permitting procedures.

5.2 Operator Attitude and Regulatory Control

Operators vary in their approach to the regulatory process. This is a legitimate issue because (according to several staff members of the regulatory authorities interviewed for this study) this attitude will affect reclamation results on the ground. The difference in attitude can be detected in the permit applications. Most companies (in the applications reviewed) have a corporate policy of cooperation with the regulatory authority. The quality of their permit applications usually is good; in some cases the baseline data and analytical techniques are excellent. These companies often have a staff of trained scientists committed to protection and enhancement of environmental resources. A few companies have taken adversarial corporate position with respect to the regulatory authority, and the quality of their baseline data is

Table 5.1-1
LIST OF INNOVATIVE PRACTICES AT CASE STUDY MINES

Case Study A	Special handling of clayey pothole soils for the restoration of wetlands.
Case Study B	Placement of prime cropland on concave landscape position to maximize snow accumulation and run-on water.
Case Study C	Monitoring vegetation quality on suspect spoil areas to determine if rehandle or cover may be necessary. 100 percent two lift direct-apply topsoiling. Retention of highwalls at existing bluffs. Use of scoria or similar soils over compacted overburden for ponderosa pine substrata (in planning).
Case Study D	Erosion-runoff plots on reclaimed and undisturbed surfaces for bond release.
Case Study E	Detailed highwall map and sampling.
Case Study F	Composite sampling of regraded spoils (disallowed by regulatory authority). Small watershed erosion study.
Case Study I	100 percent two lift direct-haul topsoiling in desert ecosystem. Use of boron-tolerant species. Non-uniform soil replacement; 12 inches on ridges and 30 inches in swales (not yet approved or implemented).
Case Study J	Use of shredded mountain shrub vegetation as a mulch in direct-haul topsoiling. Use of a semi-quantitative erosion monitoring program of revegetated lands.
Case Study L	Non-uniform topsoil thickness over spoil of varying quality.
Case Study M	Use of overburden as topsoil substitute. Use of topsoil quality evaluation system.

generally not as good. In one (approved) application reviewed, the baseline characterization, analytical techniques and reclamation planning were very poor.

The staff members of regulatory authorities know which companies are less cooperative. One stated the opinion that these companies are only doing the minimum amount possible to avoid NOV's (notice of violations) and their reclamation reflects this attitude. As a contrast, he cited another operator that is in an extremely harsh situation, works hard at reclamation, is innovative and is getting excellent reclamation results.

Many of the industry staff from cooperative operators felt that their companies ended up doing more than less cooperative operators. This opinion was expressed repeatedly. In effect, the regulatory authorities may be imposing stricter requirements on the cooperative operators and less strict on the recalcitrant. According to one soil scientist, the environmentally concerned companies comply unless the regulatory authorities ask for something unreasonable, and then they protest. If there is a problem that has a potential to damage the environment thoee companies will go out of their way to correct it. According to one scientist, who has worked for both industry and the regulatory authority, "Personally, I wouldn't stand for doing something that would damage the environment, but sometimes it's hard to take them (the regulatory authority) seriously." One staff member stated that his company was reconsidering it's policy of cooperation.

A possible resolution to the issue of encouraging innovation and maintaining regulatory control over less cooperative operators, is to leave the design standards in the regulations, but make maximum use of the phrase "unless otherwise approved by the regulatory authority." Design standards could be strictly enforced where necessary and the environmentally concerned operators could be allowed to innovate. The regulatory authorities could also use performance standards and require more rigorous analysis from less cooperative operators. The regulatory authorities also could become more stringent and refuse approval of permits that fall short of the standards set by the cooperative operators. This ideal however would depend on "regulatory authorities committed to protection of environmental resources and having the professional capabilities to make sound technical decisions, even at times deviating from the existing regulations or guidelines, while fully documenting their actions" (Fisher and Judy 1984).

Several persons expressed the opinion that the regulatory authorities need to provide better direction concerning the major problems to be addressed. Several felt that individual biases and interests at the staff level in the regulatory authority were too much of a determining factor as to what issues were considered to be problems. High turnover in the staff of the regulatory agencies also contributes to this problem. One industry scientist called this the "problem of the year syndrome." Cull (1984) refers to it as "a moving target in the dark." Fisher and Judy (1984) state that "the regulatory authority must provide better directions on baseline data collecting requirements, interpretive frameworks and overall planning directions in all phases of permitting." The task for the regulatory agencies will be to provide this direction without stifling innovation and without ignoring ecologic variability.

5.3 Findings of Reclaimability

5.3.1 Problems in the Affirmative Demonstration of Reclamation. SMCRA requires that "No permit or revision application shall be approved unless the application affirmatively demonstrates and the regulatory authority finds in writing on the basis of information set forth in the application or from information otherwise available...that...the applicant has demonstrated that reclamation as required by this Act and the State or Federal Program can be accomplished under the reclamation plan contained in the permit application" (Sec. 510a). There are differences of opinion as to what constitutes a finding of reclaimability and there is room for interpretation in the phrase "affirmatively demonstrates."

As described in section 4.0, there are of uncertainties in the baseline analyses, reclamation techniques, models of reclamation success and the criteria by which to judge reclamation success. According to the staff members of two state agencies, there are a few mines with problems that could present long term difficulties in achieving reclamation success. If each applicant had to prove beyond a shadow of a doubt that there would be no problems in reclamation, probably no mine would ever be permitted. Yet, one of the purposes of SMCRA is to "assure that the coal supply essential to the nation's energy requirements and to its economic and social well-being is provided..." (Sec. 120f). As a result, a few mines are being permitted that have potential problems of indeterminate magnitude, a situation which probably is unavoidable at this time given the state of the art.

Land use is central to the concept of reclaimability. At one case study mine, intervenors argued that the major pre-mining use of the land was scenic and recreation, and that reclamation as required by SMCRA could not be accomplished under the reclamation plan contained in the permit application. Unfortunately, the baseline characterization of pre-mining and post-mining land use is the most inexact of the baseline studies. A number of the permits reviewed contained very little land use information; several stated only that "the pre-mining land use is grazing and the proposed post-mining land use is also grazing", even though the federal rules require some quantification of land capability and productivity. Wyoming regulations specify that previous uses of the proposed permit area and adjacent lands must be "ranked on an individual basis according to the overall economic or social value of the land use to the community or area in which these lands are found" (Ch. II Sec. 2a). In the author's opinion, a more rigorous approach is needed to characterize pre-mining land uses and predict the capability and productivity of the reclaimed lands, in order to document the findings of reclaimability and demonstrate that they have been made objectively.

5.3.2 Permit Approval and Reclaimability. Several permits reviewed contained stipulations to monitor the chemistry of reconstructed soils based on the presence of deleterious chemical parameters in the overburden. It has been suggested that such permit stipulations might represent a deferral of the decision of reclaimability. Several individual regulatory scientists contend that this is not the case, but that stipulations are a normal and prudent method of monitoring reclamation practice. The stipulations in the permits reviewed, did not (with one exception) include clear statements as to how the chemical parameters will be interpreted, what will be done if a problem develops, and how such a problem might affect the viability of the reclamation plan.

One federal regulator interviewed for this study stated that no permit has ever been denied in the study area. When asked about the variability in the quality of approved baseline studies, a state regulator said that the grounds for denial on the basis of inadequate data were extremely limited due to a phrase in SMCRA that requires the regulatory authority to make it's findings based on information contained in the permit or from information otherwise available to it (Sec. 510a). He also stated that the agency felt compelled to approve some of the permit applications in order to bring the mine under compliance with the permanent regulatory inspection and enforcement program.

Another regulator suggested that it would be unlikely for a permit to get to the submittal stage if it were likely to be denied.

The findings of reclaimability may be the most difficult and comprehensive aspect of the regulatory program (section 4.4). This report documents a number of technical uncertainities that affect these findings. For example, there are uncertainties in baseline characterizations (section 4.2.3), uncertainties in overburden and spoil handling (section 4.3.2), and differences of opinion as to the adequacy of predicting and judging reclamation success (sections 4.4.2 and 4.5). There are also regulatory considerations that may have affected the findings of reclaimability. Few, if any, permits have been denied (although some people argue that there is no such thing as an unreclaimable site and others that a permit will not get to the permitting stage if it is likely to be denied). There is also the possibility that mines were permitted in order to bring them under the permanent regulatory program. A few mines have stipulations for monitoring a soil problem without a determination as to how it might affect reclaimability. Finally, there is the opinion (of at least two staff members of the regulatory authority) that it would be unrealistic to deny a permit to some existing operations on the theoretical basis of uncertain reclaimability.

In most of the thirteen case studies reviewed, there is no reason to doubt that reclamation will be successful. However, there are several mines that have problems that might affect portions of the reclaimed surfaces and may require unusual measures to achieve reclamation success, and there are differences of opinion about reclaimability at two or possibly three of the case studies reviewed. In one case, the post-mining land use objective may or may not adequately reflect pre-mine capabilities. At another, the magnitude of the acid overburden problem is not clear and the availability of sufficient cover is uncertain. At yet another, the effect of a parameter being monitored on reclaimability is not clear. Two of these cases were operating mines when permitted under the permanant regulatory program. Some workers believe that there is no such thing as an un-reclaimable site, but in the author's opinion, it is uncertain whether negative decisions of reclaimability could be made given the state of the art and the current regulatory framework.

5.4 Reclamation Success, Soil Monitoring, Bond Release

There are only minimal criteria for evaluating the reconstructed soils on reclaimed landscapes. Soil reconstruction success is presently determined primarily by soil thickness, an inadequate measure. Doll, Merrill and Halvorsen (1984) suggest that a soil productivity index should be developed to relate potential production to field, chemical, physical and mineralogical properties and to landscape position. This index could be used to judge the success of the reconstructed soil. The SCS land capability classification system, which considers rooting depth, texture, coarse fragments, slope percentage, permeability, available water holding capacity, drainage, flooding, salinity, erosion hazard, frost free period and soil moisture, is another index that could be modified to evaluate the success of soil reconstruction. According to Doll, "There needs to be a change in thinking from the simplistic view of reconstruction with available materials, to predictions and monitoring of changes to be expected due to the processes of soil development that begin to occur immediately after reclamation" (personal communication, 1985).

Monitoring is not being conducted on a routine, long-term (10 years) basis on typical reconstructed soils. In the absence of soil monitoring data, the only available measure of the soil condition will be the revegetation monitoring that will take place in years eight through ten of the bond release period. The regulatory authorities suggest that this will be a sufficient measure of soil and spoil reconstruction. There will be no data to assess the term longer than ten years, but nothing in SMCRA requires such an assessment. For the purposes of bond release, no state has approved guidelines for evaluating success of the reconstructed soil; only Montana has draft guidelines (not in effect) that address bond release criteria, such as soil erosion, in a quantitative way. Once the spoil is sampled according to the regraded spoil sampling program (if applicable), and covered with topsoil, it will not be evaluated again unless it contributes to vegetation failures.

In the author's opinion, the lack of criteria for evaluating the success of reconstructed soils, the lack of monitoring data on reconstructed soil/spoil landscapes and the lack of specific bond release criteria for reconstructed soils is a problem for two reasons. There may be cases where vegetation response in years eight through ten of the bond release period will not adequately reflect the soil conditions (section 4.6) and will not assure a permanent vegetation cover. In addition, there is a very significant difference among operators in the quality of baseline data, analytical methods and reclamation planning submitted in the permits and approved by the agencies (section 5.2). If this difference persists through the bond release process, there will be differences in the quality of the reconstructed soils on post-mining landscapes that will be more a reflection of operator attitude than available pre-mining resources.

This finding is similar to a conclusion reached by environmentalists investigating the coal enforcement program (Johnson and Hildebrandt 1984). They described a Colorado operator who argued that the law needed to be fairly and rigorously enforced with all operators or there would be difficulty enforcing it at bond release.

5.5 Research

5.5.1 Current Research. According to most people interviewed for this report, research has been curtailed drastically in the last few years.

Agencies which have contributed much to the knowledge of reclamation - USDA Forest Service SEAM program, USDA Bureau of Land Management EMRIA program, USDA Agricultural Research Service (SEA) and Argonne National Laboratories Mine Land Reclamation Program - have discontinued all or most of their research activities.

Industry personnel suggested that the regulatory authorities were attempting to shift the burden of research on to industry in the form of permit stipulations, for example basic research into the movement of soluble constitutents at the spoil/soil interface, the concentration of molybdenum in accumulator species as a function of soil chemistry and root zone thickness and the formation of acids from organic sulfur. Industry personnel suggested that their companies were willing to conduct applied research on reclamation problems specific to their mines, but felt that the regulatory authority used the leverage of permit approval to accomplish their own basic research objectives.

The North Dakota act requires the regulatory authority to provide the legislature with an annual survey of past and present reclamation research, current and future research needs, and projected estimates of funding requirements for conducting and administering reclamation research. This document is a valuable tool for anyone involved in reclamtion in North Dakota. To address problems related to soils (not overburden), research institutions in the state estimated a research budget of about $500,000 per year for the next three to five years (NDPSC and RRAC 1984). It was also estimated that approximately $13.25 million has been spent for conducting research on mining and reclamation related problems in North Dakota during the period 1970 to 1985.

5.5.2 Research Needs. Research objectives to address the uncertainties presented in this report are listed in table 5.5-1. Other workers have identified similar objectives.

Table 5.5-1
RESEARCH OBJECTIVES

BASELINE DATA COLLECTION AND ANALYTICAL TECHNIQUES

Soil Inventory and Evaluation. Reassess the adequacy of current suspect levels for soil use in reclamation (RRAC and NDPSC 1984).

Overburden Drilling Sampling and Correlation. Improve techniques of geochemical - stratigraphic correlation, and evaluate geochemistry and depositional environment.

Develop geostatistical models for drill hole location and intensity (Fransway 1984).

Acid, Alkaline, and Toxic-forming Overburden. Reassess the adequacy of current suspect levels for overburden and spoils (NDPSC and RRAC 1984).

Develop laboratory techniques of predictive value in assessing acid-base potential of overburden materials (Dollhopf and Russell 1984).

Develop overburden analytical quality assurance programs (Harrington 1984; Fransway 1984).

Continue research on the mechanisms and rates of sodium migration into topsoil from sodic spoils as a function of climate, soils and reclamation practice.

RECLAMATION TECHNIQUES

Soil Handling. Examine optimization of the topsoil resource to reduce costs and fuel requirements of topsoiling, especially over benign spoils (Larson *et al*. 1981; NDPSC and RRAC 1984).

Quantify the effects of one lift direct-haul as compared to two lift direct-haul topsoil systems on vegetation productivity, cover and diversity.

Overburden Handling. Determine the extent of spatial variability in the physical and chemical properties of graded spoils (NDPSC and RRAC 1984) and the adequacy of recontoured spoil sampling programs.

Determine the effectiveness of the mixing process under different dragline and truck-shovel operations for various parameters of concern (Fransway 1984).

Land Use and Topography. Develop quantitative methods of assessing pre-mining land use and potential and predicting post-mining land capability and stability (NDPSC and RRAC 1984).

Table 5.5-1 (continued)
RESEARCH OBJECTIVES

MODELS FOR PREDICTING RECLAMATION SUCCESS

Spoils. Develop techniques for predicting the average and standard deviation for chemical and physical spoil properties using pre-mine overburden characterization data (Doll, Merrill and Halvorsen 1984).

Predictive Models. Develop quantitative predictive models of the reconstructed soil/spoil/vegetation systems (Fisher and Judy 1984).

Develop better empirical factors for use of the Universal Soil Loss Equation on mined land or develop an alternative to predict erosion (National Research Council 1981).

EVALUATION OF RECLAMATION SUCCESS AND BOND RELEASE

Soils. Establish criteria for soil reconstruction success. Develop a soil potential index for evaluating reconstructed soil/spoil profiles (Doll, Merrill and Halvorsen 1984)

Develop quantitative methods for comparing erosion potential of reclaimed and undisturbed lands.

SOIL AND OVERBURDEN MONITORING

Soils. Develop methods for monitoring chemical and physical changes in reconstructed soils to enable accurate predications of long term of soil characteristics (Doll, Merill and Halversen 1984).

Develop methods for long term monitoring of erosion, productivity and cover of reclaimed soils to evaluate thickness requirements and erosion control methods (NDPSC and RRAC 1984).

Evaluate the use of plant quality monitoring to assess soil and overburden trace element status.

Evaluate methods of monitoring specific nutrient cycle parameters for the long term (5 to 10 years) to determine how the reconstructed soil system functions (Hargis and Redente 1984) and determine the rate at which nutrients are recycled and organic matter accumulates in replaced soil (National Research Council 1981).

Overburden. Monitor the weathering of mine spoils and the movement of soluble nutrients and the long-term implications for sustained productivity (National Research Council 1981).

6.0 CONCLUSIONS

6.1 Databases

SCS soil surveys are used as the basis for more detailed site-specific soil inventories. They are of uniform quality and readily available. Because the regulatory authorities require more detailed site-specific soil information, it is not necessary to obtain soil data from adjacent mines even though it would be useful.

Essentially no use is made of overburden data from sources other than onsite drilling. The use of data from nearby mines is unlikely because there are problems with the quality of baseline overburden data in existing permits.

An overburden geochemical database might be developed and used to extrapolate geochemistry from existing mines to new mining areas. The author suggests that overburden samples should be classified according to a uniform lithologic stystem to facilitate the establishment of an overburden database; this might improve our understanding of the geochemical, lithological, stratigraphic and depositional relationships of the coal basins.

6.2 Baseline Data Collection and Analytical Techniques

6.2.1 Soil Inventory and Evaluation. Soil baseline studies are in good shape compared to overburden baseline studies. Soils are mapped using the methods of the National Cooperative Soil Surveys which has provided a high level of quality in the soil studies compared to overburden studies.

Laboratory methods for topsoil analyses are fairly reliable agricultural soil tests. The criteria used to determine the suitability of a soil for use in reclamation are critized by industry as being agriculturally biased (not applicable to range plants), arbitrary and simplistic, but they are probably better than the criteria used to evaluate overburden suitability.

The pre-mine site-specific soil inventories delineate suitable and unsuitable soils with sufficient accuracy to plan soil handling for reclamation planning and permitting. However, the pre-mining inventories are not sufficiently accurate to predict topsoil volume in a one year salvage area or for actual salvage, and intensive staking and (in some cases) sampling is necessary prior to soil salvage.

Soil salvage depths for the same series vary significantly among mines for a number of reasons. There are chemical and physical differences within a given series, equipment limitations to salvage and variations in test results for the same material. Operators stripping the minimum amount may be concerned with soil quality and operators stripping the maximum amount may be concerned with quantity. In the author's opinion, the differences in soil salvage depths for the same series among mines suggest there are uncertainties in the characterization and handling of the soil resources that have not yet been adequately resolved.

6.2.2 Overburden Drilling, Description and Sampling. The programs for overburden characterization are full of uncertainties. One study on the intensity of drill hole spacing necessary to characterize overburden found that an inordinately high intensity of drilling was required to predict accurately the occurrence of deleterious strata. Most initial drilling programs cannot detect all occurrences or delineate the total extent of deleterious strata, but will indicate those parameters most likely to be of concern. Some available data also suggest that the accuracy of delineating unsuitable overburden zones is not much better with high intensity drilling than with lower intensity.

Lithologic descriptions in most of the permit applications reviewed are minimal. A standardized system for lithologic description would improve overburden characterizations.

In most of the cases reviewed for this study, overburden stratigraphy is not very well presented in the permit applications. In much of the coal fields of the study area the strata are lenticular, fluvial deposits that are difficult to correlate. This lenticularity may make detailed stratigraphic analysis impractical and unnecessary. However, there are certain strata that may be correlative over significant distances and certain chemical parameters that may be related to particular strata. In the author's opinion, more research needs to be done on the correlative strata and the related chemical parameters.

6.2.3 Acid, Alkaline and Toxic-Forming Overburden. The determination of acid, alkaline and toxic-forming strata is a subject of considerable debate in the industry. There are major uncertainties involving the analytical methods used and the criteria on which suitability is based.

The acid potential of the overburden and its affects on revegetation are currently judged from the measurement of acid-base potential (ABP). Acid potential is reported when the acid produced by the oxidation of sulfide minerals (principally pyrites) is greater than the neutralization potential of carbonates (principally lime). Available test methods undoubtedly do not measure the reaction as it would occur on the ground. The acid-base potential analytical method may overestimate the contribution to acidity from organic sulfurs, may not accurately reflect the stoiciometry of the oxidation of the pyrite in the presence of oxidizing bacteria and may not account for the reactivity of the lime. More work must be done on developing methods of determining the acid potential for western overburden.

Acid production from spoil underlying redressed soil could probably adversely affect western reclamation. For many years, acid formation was not considered to be a problem at western coal mines due to ubiquitous lime, but now there are mines with some acid problems.

The regulatory methods for dealing with this issue are different in each state. Wyoming DEQ now considers black carbonaceous shales and some pyritic sandstones to be potential acid-formers that may have to be specially handled and requires acid-base potential measurement on all overburden samples. The North Dakota regulatory authority considers the possibility for acid formation to be extremely limited in that state, and they do not routinely require a measurement of acid potential. The New Mexico regulatory authorities recommend an acid-base potential measurement only on non-calcareous strata. The Montana regulatory authority may require an acid-base potential measurement depending on the nature of the overburden. Colorado guidelines specify a determination of pyritic and sulfate sulfur for overburden samples. However, some reclamation specialists in industry doubt that acid formation is a potential problem. Eastern Powder River Basin mines in Wyoming are running acid-base potential on all overburden and regraded spoil samples, and special handling known acid-formers and black carbonaceous shales. In the same coal measures in Montana, acid-base potential is not typically run and is not an issue.

There has been some concern that sodium from underlying spoil would migrate into overlying soil and adversely affect the physical properties of the reconstructed soil. Some data has been presented by industry to suggest that given certain soil or climatic conditions, sodium migration should not be a problem. More recent data from one case study mine indicates that sodium migration is occurring and that redressed topsoils could become sodic in 18 to 36 years.

Toxic overburden in the form of elevated trace metal contents is an issue at three of the case study mines. The placement of overburden in the root zone which might affect plant quality (molybdenum, selenium) or revegetation success (boron) is a potential revegetation problem, but the regulatory programs for predicting whether trace metals in the spoil will be a problem may not be adequate. Monitoring plant quality on the reclaimed surface may be more effective than baseline studies of overburden trace metal content.

6.3 Reclamation Techniques

6.3.1 Soil Handling. Topsoiling ought to be an optimization process - too little soil and revegetation will be unsatisfactory; too much soil and lots of money is wasted, but topsoil handling is not optimized under the current regulatory framework. The states in the study area (with the exception of Colorado) have adopted the position that all suitable soil will be salvaged, in many cases down to depths of 60 inches or more, without regard to overburden chemical or physical parameters. In most cases soil is a better root zone material than spoil. Salvage of all suitable soil may be appropriate in many situations, but it is not appropriate in every case. Because the present baseline studies do not predict the characteristics (such as moisture holding capacity) of either the reclaimed soils or recontoured spoils, the justification for salvaging all suitable soil is not present. The available research clearly shows that where spoil can function as a root zone, very little topsoil is required for optimum revegetation success.

North Dakota and Montana require topsoil salvage and redressing in two lifts. The organic rich first lift material should have better tilth and be biologically active with microbes, seeds, and rhizomes. Having topsoil at the surface of the reconstructed soil should achieve a stable and diverse soil-vegetation system more rapidly than one lift handling which mixes topsoil and subsoil.

Soil to be used as a plant growth media is best preserved if it is direct-hauled, transferred directly from its native site to a recontoured subsoil or overburden without stockpiling. Direct-haul topsoiling may provide for better rangeland plant diversity than stockpiled soil. Existing regulations discourage direct-haul. For example, the requirement for approximate uniform thickness restricts direct-haul because direct-haul does not have the flexibility inherent in the stockpiling system. The requirement for saving all suitable soil, without a requirement for two lifts, makes the direct-haul method less effective; the biologic component of the surface layers that produces the beneficial effects of direct-haul is compromised by the requirement to salvage A, E, B, and C horizons.

For the re-establishment of rangeland, two lift direct-haul might be the best method of topsoil handling. A number of case study mines are using this system with good results. In one of the harshest sites of the five state region, the regulatory authority reports very encouraging revegetation results at a mine using the two lift direct-haul method.

The requirement for approximate uniform topsoil thickness is counter-productive in many ways. It directly conflicts with the requirement to establish a diverse plant community. In fact, uniform topsoil thickness is being interpreted in many cases to allow for non-uniform redressed thickness.

Soil volume accounting is a method that can be used to keep track of soil volumes that have been salvaged and are available for redressing. Environmental groups have criticized the enforcement of adequate soil salvage. Soil volume accounting is a reasonable requirement for mines where soil volumes are marginal and at some mines during the final years of mining where shortages of soil could be critical. However, there is no consensus that it would not be a necessary requirement at all mines.

6.3.2 Overburden Handling. Special handling, recontoured spoil sampling, 4 feet of and cover, burial or treatment are sometimes required where deleterious strata occur in the overburden or spoil. There are uncertainties involved at each step of the process.

Truck and shovel operations in Wyoming are more likely to be required to special handle material than dragline operations because the flexibility of their equipment makes it easier to do so.

Recontoured spoil sampling programs are the norm in Montana and Wyoming, but not in the other three states in the study area. The statistical validity of the recontoured spoil sampling programs has not been established. Statistical analysis of the sampling densities necessary to characterize the regraded spoil for the specific parameters of concern should be conducted at all mines with recontoured spoil sampling programs and the programs modified accordingly or discontinued. The existing programs may be giving a false sense of confidence that deleterious materials on the recontoured surface will be detected.

The requirement for 4 feet of cover over deleterious materials is a subject of debate. Federal regulations originally specified 4 feet of suitable cover over toxic spoil but this has recently been revised to "adequately covered." Wyoming still requires 4 feet, and Montana requires 8 feet; North Dakota requires up to 5 feet (a minimum of 4 feet) of cover over all spoil whether it is deleterious or not. In one New Mexico case study 18 inches of cover over sodic and clayey spoil was permitted because it was all the suitable topdressing material available.

6.3.3 Land Use and Topography. Federal regulations require that disturbed areas be restored to conditions capable of supporting the uses they were capable of supporting before mining. However, the analysis of land capability and use in the permitting process was fairly cursory in the cases reviewed. A more rigorous treatment of land capability than is presently being used in baseline studies may assure that land potentials are being protected. The USDA Land Capability Classification is an example of a system that could be used to evaluate pre-mine and post-mine land capability.

The requirement to achieve the approximate original contour may be inappropriate for the reconstructed landscape. The post-mining topography should be consistent with the hydrologic characteristics of the reconstructed soils, the revegetation communities, the reconstructed drainage systems, and the proposed post-mining land use, and should be compatible with the geomorphology of the contiguous areas to the extent possible. The analysis and design of reclaimed topography in the permits reviewed ranged from very thorough to non-existent. Researchers have suggested that the requirement to re-establish the approximate original contour is counter-productive to the best reclamation in North Dakota, but environmentalists consider the requirement for approximate original contour to be an important environmental protection in the law.

6.4 Models for Predicting Reclamation Success

When a permit application is submitted with baseline data, a mine plan and a reclamation plan, the regulatory authority must make a finding of reclaimability. This is the most comprehensive and difficult aspect of the entire regulatory program. Some workers have suggested (several persons interviewed disagree) that these findings ought to be supported to some degree by quantitative predictive models, but the findings are presently based on informal qualitative models. In actual practice the regulatory authority evaluates compliance, the spoil quality and soil thickness, the revegetation plan and revegetation success at similar mines.

Some workers suggest that the formalization and development of predictive models ought to be a research objective for the regulatory authorities, but others in industry and the regulatory authority do not agree. There are uncertainties in the reclamation of western coal lands that relate to overburden chemistry and interactions with the soil cover. In the author's opinion, if the uncertainties are to be resolved in the future, better quantitative models need to be developed to predict reclamation success and the models can be refined over time as more data become available. The models will depend on high quality baseline characterization of the soils and overburden, better criteria for the evaluation of topsoil/spoil reconstruction and better monitoring data. It is the opinion of other workers however, that quantitative models would not be better than the current system for predicting reclamation success. The regulatory authorities do not believe that anything in SMCRA authorizes the kind of monitoring that would be necessary to verify the models.

6.5 Evaluation of Reclamation Success and Bond Release

6.5.1 Reconstructed Soils. The criteria for evaluating success of the reconstruction of soils, for bond release or any other purpose, are limited. In most cases, soil reconstruction is considered to be a success if it is as thick as predicted in the baseline studies, the lifts (if required) are in the correct order and erosion does not exceed pre-mine levels. If the permit has any special stipulations regarding soils, these are also evaluated. In most stipulations for soil monitoring there are no criteria for evaluating the parameter being monitored, what would be done should a problem occur or how it might affect the viability of a reclamation plan.

Only two case study mines have quantitative measurements of erosion from reclaimed surfaces on a routine basis. There are no state guidelines for evaluating erosion of reclaimed surfaces for the purpose of bond release.

6.5.2 Recontoured Overburden. The adequacy of overburden handling and reconstruction of the root zone are evaluated based on the post-mining topography map and regraded spoil sampling program. Industry personnel suggest that the post-mining topography map should be considered an affirmative demonstration that spoil volumes are adequate and not a depiction of exactly what a given area will become a number of years in the future. The regraded spoil sampling programs are intended to determine if the chemical quality of the recontoured spoil is suitable, but there are important uncertainties involved in sampling, analyzing and interpretating the data and there are other criteria (that should be evaluated but are not) such as whether the spoil is functioning as a root zone where intended.

6.6 Soil and Spoil Monitoring

Reclaimed soil and recontoured spoils are not being monitored on a routine, long-term quantitative basis on typical reclaimed landscapes; revegetation success is being used as the indicator of the soil/spoil reconstruction success. According to some researchers (Hargis and Redente 1984):

> "Before we can say that we understand the effects of reclamation treatments we need to monitor revegetation response long enough (5 to 10 years) to see how well the system sustains vegetation production. As a basis for this we need to monitor specific nutrient cycling parameters such as mineralization and immobilization to determine how well the system functions."

Several individuals expressed the opinion that monitoring may be an important research objective but is not supported by the language of SMCRA, and that revegetation success will be an adequate indicator of the success of soil/spoil reconstruction. There are other workers of the opinion that the parameters to be measured to determine revegetation success may not be sufficient to judge the success of soil/spoil reconstruction for the establishment of a permanent vegetative cover. Several researchers and organizations have indicated a need for soil and spoil monitoring.

6.7 Comparison of State and Federal Programs

A comparison was made between the state and federal programs to determine if they were significantly different. A comparison was made between the federal act and the five state acts, and between the federal and state regulations and guidelines. The review found that in general the acts, regulations and guidelines are quite similar, but there are a few significant differences.

6.7.1 Comparison of Acts. The requirements of the acts are quite similar. A few articles are worded differently enough to have some minor effects on reclamation. For example, the federal act requires the proposed post-mining land use to be described including the lands capability to support a variety of uses, but the Montana act does not specifically mention this requirement. Grazing is the intended post-mining land use. SMCRA has provisions for experimental practice, but Montana and North Dakota have no such specific provisions.

6.7.2 Comparison of Regulations and Guidelines. In the regulations of the five states there are few major differences. Soil, topsoil, subsoil and suitable plant growth material are defined differently in the regulations.

This is an important difference because it affects the material to be salvaged and the soil handling programs. The requirement to salvage one or two lifts of soil is another important difference; Montana and North Dakota require two, the other states require one. All five states require uniform thickness but Montana permits non-uniform application for special soil reconstruction. The required depth of cover over toxic or acid-forming material is quite variable.

6.8 Innovation, Ecologic Variability and Regulatory Flexibility

6.8.1 The Need for Innovation. The need for innovation is an important issue. Reclamation in the west is a new science and it is critical that it be allowed to improve. Whether or not there is sufficient flexibility under the existing regulatory framework is a matter of perspective. Many industry scientists believe there is not; environmentalists and regulators contend there is.

There is a continuing debate between industry on one side and the regulatory authority and environmentalists on the other, on the need for design standards versus performance standards and their affect on innovation. Every operator interviewed expressed a preference for performance standards rather than design standards. From their perspective the movement away from design standards as the result of recent judicial decisions is a welcome trend. They regard performance standards as the most economic and effective approach to assure successful reclamation. However, in the author's opinion, there is some doubt that performance standards can be enforced because there are so few criteria for evaluating soil/spoil reconstruction and very little monitoring of reconstructed soil/spoil profiles.

OSM was repeatedly critized by industry (and by a few state regulatory agency personnel) for being too inflexible (although this study did identify several cases of flexibility on the part of OSM). Naturally, the states argued for more state control. OSM may be trying to regulate the guidelines on a uniform basis so that they avoid allowing a practice in one place and disallowing it in another. This kind of regulation could be detrimental to innovation.

The use of guidelines as opposed to rules may affect regulatory flexibility. Some states are reluctant to have guidelines because guidelines may be interpreted too rigidly. Some state guidelines have been undergoing revisions for years. This creates problems for the industry, but does have the advantage of providing for evolution essential to the growth of the science of reclamation.

6.8.2 Innovative Practices. This report contains a list of innovative practices at the case study mines. Eighteen innovative practices are listed from 13 case study mines. None of these were permitted under the experimental practice provision of the regulations.

6.9 Operator Attitude and Regulatory Control

Operators vary in their approach to the regulatory process and, according to the regulatory authority, this will affect reclamation results on the ground. Most companies (in the operations reviewed) have a corporate policy of cooperation with the regulatory authority. A few companies have apparently taken a adversarial position with regard to the regulatory authority. Many of the staff from cooperative operators felt that their companies ended up doing more than the less cooperative companies. In effect the regulatory authority may be imposing stricter requirements on the cooperative operators and less strict on the recalcitrant. One staff member stated that his company was reconsidering it's policy of cooperation.

A possible resolution to the issue of encouraging innovation and maintaining regulatory control is to leave the design standards in the regulations, but make maximum use of the phrase "unless otherwise approved by the regulatory authority." Design standards could be strictly enforced where necessary and the innovative, environmentally concerned operators could be allowed to innovate.

Several individuals expressed the opinion that there needs to be better direction from the regulatory authority concerning the major problems to be addressed. The task for the regulatory agencies will be to provide this direction without stifling innovation and without ignoring ecologic variability.

6.10 Findings of Reclaimabilty

6.10.1 Problems in the Affirmative Demonstration of Reclamation. SMCRA requires that the application affirmatively demonstrates that reclamation can be accomplished. There are uncertainties in the baseline analyses, reclamation techniques, models of reclamation success and the criteria by which to judge reclamation success. One of the purposes of SMCRA is to assure that the coal supply essential to the nation's energy requirements and to its economic and social well-being is provided. As a result, a few mines are being permitted that have potential problems of indeterminate magnitude, a situation which is probably unavoidable at this time given the state of the art.

Land use is central to the concept of reclaimability. Unfortunately, the baseline characterization of pre-mining and post-mining land use is the most inexact characterization in the baseline studies. In the author's opinion, a more rigorous approach is needed to characterize pre-mining land uses and predict the capability and productivity of the reclaimed lands, in order to document the findings of reclaimability and demonstrate that the findings have been made objectively.

6.10.2 Permit Approval and Reclaimability. Several permits reviewed contained stipulations to monitor the chemistry of reconstructed soils based on the presence of deleterious chemical parameters in the overburden. These stipulations ought to include clear statements as to how the parameters will be interpreted, what will be done if a problem develops and how such a problem might affect the viability of the reclamation plan.

In most of the case studies reviewed, there is no reason to doubt (based on soil/spoil reconstruction) that reclamation will be sucessful. However, there are differences of opinion about reclaimability at two or possibly three case study mines. In the author's opinion, it is uncertain whether negative decisions of reclaimability could be made given the state of the art and the current regulatory framework.

6.11 Reclamation Success, Soil Monitoring and Bond Release

There are only minimal criteria for evaluating the reconstructed soils on reclaimed landscapes. Soil reconstruction success is presently determined by soil thickness, an inadequate measure. A soil productivity index should be developed to relate potential production to field, chemical, physical and mineralogical properties and to landscape position. This index could be used to judge the success of the reconstructed soil. The SCS land capability classification system, which considers numerous soil, landscape and climatic parameters, is an example of another index that could be modified to evaluate the success of soil reconstruction.

Monitoring is not being conducted on a routine, long-term basis (10 years) on typical reconstructed soils. In the absence of soil monitoring data, the only available measure of the soil condition will be the revegetation monitoring. For the purposes of bond release, no state has approved guidelines for evaluating success of the reconstructed soil. The regulatory authorities suggest that the success of revegetation will be a sufficient measure of soil and spoil reconstruction, but once the spoil is sampled according to the regraded spoil sampling program (if any) and covered with soil, it will not be evaluated again unless it contributes to vegetation failures.

In the author's opinion, the lack of criteria to evaluate the success of reconstructed soils, the lack of monitoring data on reconstructed soil/spoil landscapes and the lack of specific bond release criteria for reconstructed soils, is a problem for two reasons. There may be cases where vegetation response in years eight through ten of the bond release period will not adequately reflect the soil conditions and will not assure a permenent vegetation cover. In addition, there is a very significant difference in the quality of baseline data, analytical methods and reclamation planning submitted in the permits and approved by the agencies. If this difference persists through the bond release process there will be differences in the quality of the reconstructed soils on post-mining landscapes, that will be more a reflection of operator attitude than avaliable pre-mining resources.

6.12 Research

6.12.1 Current Research. Research has been drastically curtailed in the last few years. Some individuals suggested that the regulatory authority may be attempting to shift the burden of research on to the operators in the form of permit stipulations. They suggest that the companies are willing to conduct applied research on reclamation problems specific to their mines, but felt that the regulatory authority used the leverage of permit approval to accomplish their own basic research objectives.

6.12.2 Research Needs. A table presents a number of research needs, necessary to resolve the uncertainties presented in this report.

REFERENCES CITED

American Geological Insititute. 1962. Dictionary of geological terms. Dolphin Books, Doubleday and Company, Inc., Garden City, New York.

Barth, R.C. and B.K. Martin. 1982. Soil depth requirements to reclaim surface - mined areas in the northern Great Plains. Colorado School of Mines Res. Inst., Golden.

Bauer A., et al. 1978. Fertilization of wheat, corn, and grass-legume moisture grown on reclaimed spoilbanks. Res. Rpt. 67. N. Dak. Agr. Exp. Sta., Fargo.

Boon, D., P. Smith and K. Lawton. undated. Carbonaceous materials problems associated with successful reclamation, unpublished draft, Wyoming Department of Environmental Quality, Land Quality Division, Cheyenne, Wyoming.

Bruhn, R. et al. 1980. An assessment of the feasibility of developing a toxic overburden detection system for surface coal mine applications in the western United States. U.S. Bureau of Mines Final Rep. on Contract J0188051.

Bureau of Mines. 1981. Selective placement of strip mine overubrden, V summary report. Reclamation Research Unit, Mont. Agr. Exp. Sta., Bozeman.

Carlstrom, Mark and Neil Harrington. 12 March 1984. Memorandum to: Department of State Lands round-robin participants. Department of State Lands, State of Montana. Helena, Montana.

Caruccio, Frank T., et al. 1977. Paleoenvironment of coal and its relation to drainage quality. EPA-600/7-77-067 Ind. Env. Res. Lab., Off. Res. Dev. Cincinnati, Ohio.

Colorado Legislature. 1983. Colorado Surface Coal Mining Reclamation Act. Mined Land Reclamation Division, Denver, Colorado.

Cull, C.A. 1984. Regulatory interpretation: Does it resolve or complicate environmental concerns associated with surface coal mining? Presented to: Second Annual Regional Conference on Precious Metals, Coal, Industrial Minerals and Environment, Black Hills Section SME/AIME, Rapid City South Dakota.

DSL (Department of State Lands). 1980. Montana's permanent program strip and underground mine reclamation rules and regulations. DSL, Helena, Montana.

DSL (Department of State Lands). 1982. Bond release guidelines for coal mine reclamation, draft #2. DSL, Helena, Montana.

DSL (Department of State Lands). 1983. Proposed soil and overburden guidelines. DSL, Helena, Montana.

Dansdill, Bob and Arnold King. 1978. Guide for determining capability class. In Technical Notes, Agronomy Note #56. USDA, SCS, Colorado.

David Stiller and Associates. 1983. A review of soil erosion and sediment yield measurement methods and proposed guidelines. David Stiller and Associates, Helena, Montana.

Doll, E.C. 1985 personal communication. N. Dak. Agr. Exp. Sta. Fargo.

Doll, E.C., S.D. Merrill and G.A. Halvorsen. 1984. Soil replacement for reclamation of strip mined lands in North Dakota. N. Dak. Agr. Exp. Sta., Fargo.

Dollhopf, D.J., et al. 1981. Selective placement of strip mine overburden in Montana, V summary report. U.S. Bureau of mines Contract HO262032.

Dollhopf D.J. and Goering, J.D. 1983. New drilling greases that will not contaminate overburden samples. In 1983 Symposium on Surface Mining, Hydrology, Sedimentology and Reclamation. University of Kentucky, Lexington, Kentucky, November 27-December 2, 1983.

Dollhopf, D.J. et al. 1985. Chemical amendment and irrigation effects on sodium migration and vegetation characteristics in 7-year old sodic mine soils. Montana Ag. Exp. Station, Mt. State Univ. Bozeman, SR-17, January 1985.

Dollhopf, D.J., and L.J. Russell. 1984. Assessment of acid producing materials in the northern plains. In third biennial Symposium on Surface Coal Mine Reclamation on the Great Plains. Billings, Montana, March 1984.

Ferm, J.C., and G.A. Weisenfluh. 1981. Cored Rocks of the Southern Appalachian Coal Fields. Department of geology, University of Kentucky. Lexington, Kentucky.

Ferm, J.C., G.C. Smith, G.A. Weisenfluh, and S.B. Dubois. 1985. Cored rocks in the Rocky Mountain and High Plains Coal Fields. University of Kentucky, Lexington.

Fisher, Scott E. Jr. and Clark Judy. 1984. Resource perspectives of the surface coal mine regulatory system, unpublished.

Fisher, Scott E. Jr. personal communication, 1985.

Fransway, Dennis. 1984. Future research needs in mine land reclamation, In Soils and Overburden in Reclamation of Arid/Semiarid Mined Lands Proceedings of the Symposium. Casper, Wyoming, January 20-21, 1984.

Groenewold, Gerald H. and Bernard W. Rehm. 1980. Instability of contoured surface-mined landscapes in the Northern Great Plains: causes and implications. In Adequate Reclamation of Mined Lands? - Symposium. Soil Conservation Society of America and WRCC - 21, Billings, Montana, March 26-27, 1980.

Halvorsen, G.A., L.V. Zimmerman, and S.W. Melsted. 1981. Nitrogen and phosphorus fertilization of strip mined lands in western North Dakota. 1981. Agronomy Abstracts, Am. Soc. Agron., Madison, Wisconsin.

Hargis, Norman E. and Edward F. Redente. 1984. Soil handling for surface mine reclamation. J. Soil and Water Cons. 39:300-305.

Harrington, Neil. 1984. Issues in soils and land reclamation. In Montana Soil Science Newsletter, volume 84, number 2. Cooperative Extension Service. Montana State University, Bozeman, Montana.

Heil, Robert D, and Caroline M. Yonker. 1982. Research and development of natural resource information systems, In Proceedings of a Symposium, Mining and Reclamation of Coal Mined Lands. Billings, Montana March 8-9, 1982.

Jansen, I.J., W.S. Dancer, and R.E. Dunker. 1981. Row crop response to replacement of soil A horizon material after surface mining. 1981 Agronomy Abstracts, Am. Soc. Agron., Madison, Wisconsin, p. 199.

Jastrow, J.D., et al. in press. Revegetation of disturbed lands in arid ecosystems. In Ecological Studies of Disturbed Landscapes. US Department of Energy, Office of Energy Research, Washington, D.C.

Johnson, C.R. and E. Hildebrandt. 1984. Still stripping the law on coal. National Resources Defense Council, Inc. Denver, Colorado.

Klusman, Dr. Ronald W. 1980. Sampling designs for geochemical baseline studies in the Colorado oil shale region: a manual for practical application. U.S. Department of Energy, Office of Health and Environmental Research, Washington, D.C.

Larson, William E., et al. ed. 1981. Soil and water resources: research priorities for the nation. Soil Science Society of America, Inc., Madison, Wisconsin.

MLRD (Mined Land Reclamation Division). 1981. Regulations of the Colorado Mined Land Reclamaton Board for coal mining. Colorado Department of Natural Resources, Denver, Colorado.

MLRD (Mined Land Reclamation Division). 1982. Guidelines for the collection of baseline water quality and overburden geochmeistry data. Colorado Department of Natural Resources, Denver, Colorado.

MMD (Mining and Minerals Division). 1984. Overburden and soils inventory and handling guidelines. Draft, Energy and Minerals Department, Santa Fe, New Mexico.

MMD (Mining and Minerals Division). 1980. State of New Mexico surface coal mining regulations. Energy and Minerals Department, Santa Fe, New Mexico.

McGinnies, W.J., and P.J. Nicholas. 1980. Effect of topsoil thickness and nitrogen fertilizer on the revegetation of coal mine spoils. J. Environ. Qual. 9: 681-685.

Miyamoto, S. 1983. Potential sodification of topdressed profiles and its implication to vegetation stability at the San Juan Mine, New Mexico. An Assessment Report submitted to: San Juan Coal Company, Waterflow, New Mexico.

Montana. Legislature. 1981. The Montana Strip and Underground Mine Reclamation Act. MCA, Helena, Montana.

Montana Coal Council. 1984. Definitions and strip mine permit application requirements. Helena, Montana.

Munshower, Dr. Frank F. undated. Microelements and their role in surface mine planning. Mont. Agr. Exp. Sta., Bozeman.

NDPSC (Public Service Commission of North Dakota). 1983. Public Service Commission State of North Dakota rules governing the reclamation of surface-mined land. Public Service commission, Bismarck, North Dakota.

NDPSC (Public Service Commission of North Dakota). 1984. Policy memorandums no. 1, 3 and 5 to mine operators. Public Service Commission, Bismarck, North Dakota.

NDPSC (Public Service Commission of North Dakota) and RRAC (Reclamation Research Adviaory Committee). A report on reclamation research in North Dakota: inventory of past and ongoing research and identification of future research needs. Prepared for the North Dakota Legislative Council, Bismarck, North Dakota.

Naftz, David. 1984. In-house Wyoming DEQ memo dated 6 June 1984 to Lawton and others re application of nested analysis of variance when determining sampling intensities on regraded spoils for balanced data.

National Research Council. 1981. Surface mining: soil, coal, and society. National Academy Press, Washington, D.C.

Neuman, D.R. and F.F. Munshower. 1983. Copper molybdenum uptake by legumes growing on topsoiled mine spoils, final report. Reclamation Research Unit, Mont. Agr. Exp. Sta., Bozeman.

New Mexico. Legislature. 1979. Surface Mining Act. HENRCS/House Bill 371, Santa Fe, New Mexico.

North Dakota. Legislature. 1979. Reclamation of Surface-Mined Land. Public Service Commission, Bismarck, North Dakota.

Packer, Paul E., et al. 1982. Models to estimate revegetation potentials of land surface mined for coal in the west. USDA, Forest Service, General Technical Report INT-123.

Page, A.L. edit. 1982. Methods of soil analysis part 2, chemical and microbiological properties, second edition. American Society of Agronomy, Inc. and Soil Science Society of America, Inc. Madison, Wisconsin.

OTA (Office of Technology Assessment), Congressional Board of the 98th Congress. 1984. Environmental protection in the federal coal leasing program. U.S. Congress, OTA-E-237, Washington, D.C.

Power, J.F., et al.1981. Effects of topsoil and subsoil thickness on water content and crop production on a disturbed soil. Soil Sci. Soc. Am. J. 45: 124-129.

Public law 95-87, 95th Congress. 1977. Surface Mining Control and Reclamation Act of 1977.

Rounsaville, Hayden D. 1977. Guidelines for estimating potential land capability and range sites as a part of reclamation planning and alternative analysis - Thunder Basin National Grasslands. USDA, Forest Service, Medicine Bow National Forest, Rocky Mountain Region.

Russell, L.J. 1984. Assessment of acid producing materials in the northern plains. In Third Biennial Symposium on Surface Coal Mine Reclamation on the Great Plains. Billings, Montana, March 1984.

Schafer, William M. 1982 Changes in land capability class resulting from mining in the northern Great Plains. In Proceedings of a symposium Mining and Reclamation of Coal Mined Lnads in the Northern Great Plains. Billings, Montanna, March 8-9, 1982.

Schuman, G.E., and J.F. Power. 1981. Topsoil management on mined lands. J. Soil and Water Cons. 36: 77-78.

Severson, R.C. 1984. Soil and Overburden sampling needs and programs. In Third Biennial Symposium on Surface Coal Mine Reclamation on the Great Plains. Billings, Montana, March 1984.

Severson, R.C., and S. Fisher. 1985. Results of the first western task force round-robin soil and overburden analysis program. USGS open-file report 85-220.

Singleton, P.C. and D.A. Barker, 1979. Soil development and nitrates in mine soil. EPA-600/7-79-253. Ind. Res. Lab., Off. Res. Develop., Cincinnati, Ohio.

Smith, Richard M., et al. 1974. Mine spoil potential for soil and water quality. NTIS, PB-237 525, US Department of Commerce, Richfield, Virginia.

Snarski, R.R., J.B. Fehrenbacher and I.J. Jansen. Physical and chemical characteristics of pre-mine soils and post-mine soil mixtures in Illinois. Soil Science, Vol. 45, No.4, July-August 1981.

30 CFR 700.1. 1983. Code of federal regulations, mineral resources. Office of the Federal Register, Washington, D.C.

Tresler, R.L. 1974. Strip mine reclamation in Wyoming. In Proc., Sec. Res. Applied Tech. Symp., on Mined-land Recla. Nat. Coal Assoc., Washington, D.C. pp. 22-28.

Sindelar, B.W., R.L. Hodder, and M.E. Majerus. 1973. Surface mined land reclamation research in Montana. Res. Rpt. 40. Mont. Agr. Exp. Sta., Bozeman.

USDA (United States Department of Agriculture), U.S. Salinity Laboratory Staff, Soil Conservation Service. 1969. Diagnosis and improvement of saline and alkali soils. Agricultural Handbook No. 60, USDA, Washington, D.C.

USDA (United States Department of Agriculture), Soil Conservation Service, Soil Survey Staff. 1951. Soil Survey Manual, Agriculture handbook No. 18. USDA, Washington, D.C.

USDA (United States Department of Agriculture), Soil Conservation Service, Soil Survey Staff. 1975. Soil Taxonomy - a basic system of soil classification for making and interpreting soil surveys, Agricultural Handbook No. 436. USDA, Washington, D.C.

USDA (United States Department of Agriculture), Soil Conservation Service, 1983. National Soils Handbook. USDA, Washington, D.C.

USDA (United States Department of Agriculture), Soil Conservation Service. 1977. Preliminary guidance for estimating erosion on areas disturbed by surface mining activities in the interior Western United States, Interim Final Report. Environmental Protection Agency, EPA-908/4-77-005, Washington, D.C.

USGS (United States Geological Survey). 1980. A climatic appraisal of the rehabilitation potential of strippable coal lands in the Green, Yampa and White River Drainage Basins, Colorado, Utah and Wyoming. Map MF-1212, Washington, D.C.

WDEQ (Wyoming Department of Environmental Quality). 1980. Rules and regulations, Wyoming Department of Environmental Quality, Land Quality Division. WDEQ, Cheyenne, Wyoming.

WDEQ (Wyoming Department of Environmental Quality). 1984. Wyoming Department of Enviornment Quality, Land Quality Division, Guideline No. 1, topsoil and overburden. WDEQ, Cheyenne, Wyoming.

Western Resource Development Corp. and J. Bunin. 1985. Revegetation Technology and Issues at Western Surface Coal Mines. Contractors Report to US Congress, Office of Technology Assessment.

Western Water Consultants Inc. 1985. Hydrologic Technologies for Western Surface Coal Mining. Contractors Report to US Congress, Office of Technology Assessment.

Wyoming. Legislature. 1980. Wyoming Environmental Quality Act. Cheyenne, Wyoming.

GLOSSARY

Aeolian--Deposits which are due to the transporting action of the wind.

Alluvium--Sand, silt, or clay that has been deposited on land by streams.

Aridisols--Mineral soils that have an ardic moisture regime, an ochric epipedon, and other pedogenic horizons but no oxic horizon. (A suborder in the USDA soil taxonomy.)

Available water--The portion of water in a soil that can be absorbed by plant roots. The amount of water released by the soil when the equilibrium soil water matrix potential is decreased from field capacity to -15 bar.

Bench--A thickness of overburden handled as a layer.

Calcareous--Soil containing sufficient free calcium carbonate or calcium-magnesium carbonate to effervesce visibly when treated with cold 0.1N hydrocholoric acid.

Classification, soil--The systematic arrangement of soils into groups or categories on the basis of their characteristics. USDA soil classification system (soil taxonomy) was adopted for use in publications by the National Cooperative Soil Survey.

Coal stringers--Layers of coal too thin to salvage.

Competent--Resistant.

Consociations--A soil map unit comprised mostly of one soil type.

Correlation--See stratigraphic correlation.

Dip--The angle that a structural surface, i.e., bedding, makes with the horizontal measured perpendicular to the strike.

Entisols--Mineral soils that have no distinct pedogenic horizons within 1 m of the soil surface. (A order in the USDA soil taxonomy.)

Erosion--The group of processes whereby earth or rock material is loosened or dissolved and removed from any part of the earth's surface.

Feldspathic--Containing the mineral feldspar.

Flood plan--Nearly level land, consisting of stream sediments, that borders a stream and is subject to flooding unless protected artifically.

Fluvial--Of or pertaining to rivers; a feature produced by river action, i.e., a fluvial plain.

Friable--A consistency term pertaining to the ease of crumbling of soils.

Geomorphology--Pertaining to the form of the earth or its surface features; i.e., a geomorphic province.

Hogback--A sharp crested ridge formed by the outcropping edges of steeply inclined resistant rocks.

Horizon soil--A layer of soil, approximately parallel to the surface, that has distinct characteristics produced by soil-forming processes.

Immobilization--Unavailable to plants.

Infiltration--The downward entry of water into the soil.

Infiltration rate--The rate at which water enters the soil; it has the dimensions of velocity.

Isopach--Lines of equal thickness.

Lenticular--Stratigraphic units that are discontinuous horizontially.

Lithology--The physical character of a rock.

Macronutrient--A chemical element necessary in relatively large amounts (usually > 500 ppm in the plant) for the growth of plants. These elements consist of C, H, O, Ca, Mg, K, P, S, and N.

Micronutrient--A chemical element necessary only in extremely small amounts (usually < 50 ppm in the plant) for the growth of plants. These elements consist of B, Cl, Cu, Fe, Mn, Mo, and Zn.

Mollic epipedon--A surface horizon of mineral soil that is dark colored and relatively thick, contains at least 0.58% organic carbon, is not massive and hard or very hard when dry, has a base saturation of more than 50% when measured at pH 7, has less than 250 ppm of P_2O_5 soluble in 1% citric acid, and is dominately saturated with bivalent cations.

Mollisols--Mineral soils that have a mollic epipedon overlying mineral material with a base saturation of 50% or more when measured at pH 7. Mollisols may have an argillic, natric, albic, cambic, gypsic, calcic, or petrocalcic horizon, a histic epipedon, or a duripan, but not an oxic or spodic horizon. (Order in the USDA soil taxonomy.)

Monotoxonomic--Consociations.

Morphological--Soil form (see morphology.)

Mycorrhiza--Literally "fungus root". The association, usually symbiotic, of specific fungie with the roots of higher plants.

Mycorrhizal--pertaining to mycorrhiza.

Paralithic contact--Similar to a lithic contact except that the mineral material below the contact has a hardness of less than 3 (Mohs scale), and gravel size chunks that can be broken out; will partially disperse within 15 hours shaking in water or sodium hexametaphosphate solution.

Partings--Thin shale layers within the coal seam.

Pedestalling--Small pedestals formed under stones from erosion.

Pedologic--Pertaining to soils.

Pedon--A three dimensional body of soil with lateral dimensions large enough to permit the study of horizon shapes and relations. Its area ranges from 1 to 10 square meters.

Phase, soil--A subdivision of a soil type or other unit of classification having characteristics that affect the use and management of the soil but which do not vary sufficiently to differentiate it as a separate type. A variation in a property or characteristic such as degree of slope, degree of erosion, content of stones, etc.

Phytoxic--toxic to plants.

Pinch out--Lenticular.

Playa--An intermittent shallow pond.

Profile, soil--A vertical section of the soil through all its horizons and extending into the parent material.

Regolith--Loose, incoherent weathered rock below the soil.

Rider seams--Thin coal seams above the main coal.

Saline seeps--Spring water soluble salts accumulate at the ground surface.

Scalping materials--Coal wastes.

Scoria--Rock material affected by the burning of underlying coal.

Silicious--Pertaining to silicate rocks.

Slope classes--A range of slope exressed as a percent i.e., 0-5%.

Sodium Adsorption Ratio (SAR)--A relation between soluble sodium and soluble divalent cations which can be used to predict the exchangeable-sodium percentage of soil equilibrated with a given solution. It is defined as follows:

$$\text{SAR} = \frac{\text{sodium, mmoles/liter}}{(\text{calcium} = \text{mangnesium})1/2(\text{mmoles/liter})1/2}$$

Soil--(i)The unconsoidated mineral material on the immediate surface of the earth that serves as a natural medium for the growth of land plants. (ii) The unconsolidated mineral matter on the surface of the earth that has been subjected to and influenced by genetic and environmental factors of: parent material, climate (including moisture and temperature effects), macro- and microorganisms, and topography, all acting over a period of time and producing a product--soil--that differs from the material from which it is derived in many physical, chemical, biological and morphological properties, and characteristics.

Soil morphology--The physical constitution, particularly the structural properties, or a soil profile as exhibited by the kinds, thickness, and arrangement of the horizons in the profile, and by the texture, structure, consistency, and porosity of each horizon.

Soil series--The basic unit of soil classification being a subdivision of a family and consisting of soils which are essentially alike in all major profile characteristics except the texture of the A horizon.

Soil structure--The combination or arrangement of primary soil particles into secondary particles, units, or peds.

Stoichiometry--The calculation of combining weights of reactants and products and products in a chemical reaction.

Stratigraphic correlations--The process by which stratigraphic units in two or more separate areas are shown to be laterally similar in character or mutually correspondent in stratigraphic position.

Stratigraphy--The arrangement of strata.

Strike--The direction or trend taken by a structural surface, i.e., bedding.

Subsoil--The soil horizons underlying the topsoil, typically the B and C horizons.

Surface soil--The uppermost part of the soil, ordinarily moved in tillage or its equivalent in uncultivated soils and ranging in depth from 3 or 4 inches to 8 or 10. Frequently designated as the "plow layer", the "Ap layer", or the "Ap horizon."

Swales--Shallow valleys.

Swell factor--The amount of expansion on excavation expressed as a multiple of one or a percent.

Till--Unstratified glacial drift deposited directly by the ice and consisting of clay, sand, gravel, and boulders intermingled in any proportion.

Tilth--The physical condition of soil as related to its ease of tilage, fitness as a seedbed, and its impedance to seedling emergence and root penetration.

Topsoil--(i)The surface horizons of a soil, typically A and E horizons. (ii) The materials used as a top dressing for soil reconstruction over regraded spoil.

Topsoiling--The application of soil materials over spoil.

Revegetation Technology & Issues at Western Surface Coal Mines

prepared for

Energy & Materials Program
Office of Technology Assessment
United States Congress
Washington, D.C. 20510

prepared by

Western Resource Development Corporation
711 Walnut Street P.O. Box 467 Boulder, Colorado 80306

in conjunction with

Jane Bunin, Ph.D.
3010 Regis Avenue Boulder, Colorado 80303

September 1985

TABLE OF CONTENTS

Section Page

Executive Summary. i

1.0 INTRODUCTION 1
  1.1 Objectives 1
  1.2 Background 2
  1.3 Research Methods and Sources 3
  1.4 Phases of Study. 4

2.0 OVERVIEW 8
  2.1 Environment of the Study Region. 8
    2.1.1 Vegetation 8
    2.1.2 Environment. 12
  2.2 Historical Perspective on Mine Revegetation. 13
  2.3 Requirements for Baseline Data 14
    2.3.1 Background 14
    2.3.2 State Requirements as Related to Land Use. . . . 16
      2.3.2.1 Vegetation Maps. 17
      2.3.2.2 Production 20
      2.3.2.3 Cover. 29
      2.3.2.4 Woody Plant Density. 30
      2.3.2.5 Lifeform and Species Diversity 36
  2.4 Existing Sources of Baseline Data. 37
    2.4.1 Range Data 37
    2.4.2 Reearch Data 40
    2.4.3 Mine Permit Application Data 40
      2.4.3.1 Colorado 41
      2.4.3.2 Montana. 41
      2.4.3.3 New Mexico 44
      2.4.3.4 North Dakota 44
      2.4.3.5 Wyoming. 44
  2.5 Revegetation Monitoring Requirements 45
  2.6 Revegetation Data and Planning 46
    2.6.1 Existing Sources of Revegetation Data. 46
    2.6.2 Reclamation Seed Mixes 48
  2.7 Revegetation Performance Standards 49
  2.8 Methods of Predicting and Evaluating Revegetation Success 56
    2.8.1 Predicting Revegetation Success. 56
    2.8.2 Evaluating Revegetation Success. 58
      2.8.2.1 Unadjusted Baseline. 59
      2.8.2.2 Control Areas. 59
      2.8.2.3 Reference Areas. 61
      2.8.2.4 Historic Record. 62
      2.8.2.5 Technical Standards. 63
  2.9 Revegetation Research and Innovation 63
    2.9.1 Direct Haul or "Live" Topsoiling 72
    2.9.2 Newly Available Plant Material 81
    2.9.3 Minimizing Competition to Enhance Lifeform and Species Diversity 83

TABLE OF CONTENTS (continued)

Section Page

2.9.4 Minimal Fertilization. 84
2.9.5 Management of Grasslands 85
2.9.6 Technology of Shrub Establishment. 86
2.9.7 Mulching 87
2.9.8 Irrigation 89
2.9.9 Landscape Diversity. 91
2.9.10 Revegetation Equipment 92
2.9.11 Permit Revisions Involving Revegetation. 93

3.0 CASE STUDIES 95
3.1 Selection Criteria 95
3.2 Full Case Study Synopses 95
3.2.1 Colorado. 96
3.2.1.1 Case Study Mine CO-1. 96
3.2.1.2 Case Study Mine CO-2. 98
3.2.2 Montana 100
3.2.3 North Dakota. 106
3.2.4 New Mexico. 112
3.2.4.1 Case Study Mine NM-1. 112
3.2.4.2 Case Study Mine NM-2. 114
3.2.4.3 Case Study Mine NM-3. 116
3.2.5 Wyoming 119
3.2.5.1 Case Study Mine WY-1. 119
3.2.5.2 Case Study Mine WY-2. 121
3.2.5.3 Case Study Mine WY-3. 123
3.2.5.4 Case Study Mine WY-4. 125
3.3 Partial Case Studies 128
3.3.1 Colorado. 128
3.3.2 Montana 129
3.3.3 North Dakota. 130
3.3.4 Wyoming 130

4.0 ANALYSIS 132
4.1 Applicability of Existing Baseline Data. 132
4.1.1 Range Management and Research Programs 132
4.1.2 Mine Permit Applications 135
4.2 Applicability of Monitoring and Research Data. 137
4.3 Effectiveness of Current Methods for Setting Revegetation Performance Standards 138
4.3.1 Cover and Production 138
4.3.2 Woody Plant Density. 140
4.3.3 Diversity. 142
4.4 Achievement of Performance Standards Under SMCRA . . . 148
4.4.1 Cover and Production 148
4.4.2 Woody Plant Density. 151
4.4.3 Lifeform and Species Diversity 153
4.5 Test Grazing 154
4.5.1 Livestock Use and Response to Grazing. 155
4.5.2 Test Grazing Data. 156

TABLE OF CONTENTS (continued)

Section Page

4.5.3 Regulation of Test Grazing 158
4.5.4 Summary. 158

5.0 ISSUES ANALYSIS. 161
5.1 Use of Native Versus Introduced Species. 161
5.2 Use of Shrubs. 163
5.2.1 Conflict with Grazing Use and Range Improvement Programs 164
5.2.2 Importance to Wildlife 166
5.2.3 Other Important Aspects of Woody Plants. 167
5.3 Importance of Lifeform and Species Diversity 168
5.4 Achievement of Landscape or Community Diversity. . . . 169
5.5 Assessment of Revegetation Permanence. 171
5.6 Development of Improved Performance Standard Systems for Cover and Production 173
5.7 Use of Design Standards in Revegetation Process. . . . 175
5.8 Roles of Industry and Regulatory Authorities in Innovation. 177
5.8.1 Overview 177
5.8.2 "Seeding" with Live Topsoil. 181
5.9 Collection and Use of Monitoring Data. 182
5.10 Appropriateness of Statistical Methods 183
5.11 Bond Release 184
5.12 Future Research Priorities 186

7.0 REFERENCES 188

Appendix A Groups and Individuals Contacted 206

Appendix B Seed Mixes 213

Appendix C Glossary 233

LIST OF TABLES

Table		Page
1	Selected Current Requirements for Vegetation Baseline Data by State	18
2	Selected Vegetation Data Included in Permit Application on File at OSM	42
3	Revegetation Performance Standards by Land Use Category	50
4	Summary of Systems for Evaluating Revegetation Success	60
5	Survey of Research Center Revegetation Programs in the Study Area	64
6	Survey of Industry Innovation and Experimentation at Study Area Mines	73
7	State Requirements Concerning Test Grazing	159

INTENTIONAL
BLANK

LIST OF FIGURES

Figure Page

1 Location map showing major ecological provinces in the study region. 10

2 Excerpt from an SCS range site description 21

3 Range site map for an area of the Northern Great Plains 23

4 Excerpt from a vegetation type description 24

5 General vegetation type map for an area of the Northern Great Plains. 26

6 Detailed vegetation map from the northern portion of the study region. 27

7 Graphic representation of a production sampling plot . . 28

8 A point-frame, one method for measuring vegetation cover 31

9 Graphic representation of a point intercept transect . . 32

10 Graphic representation of a line intercept transect. . . 34

11 Example of a caulation of the Shannon Index. 144

12 Example of a calculation of the Motyka Index 145

EXECUTIVE SUMMARY

This report describes a study conducted for the Office of Technology Assessment (OTA) by Western Resource Development Corporation (Dr. David L. Buckner, Principal Investigator and Dr. Allen B. Crockett, third author) in conjunction with Dr. Jane E. Bunin. The main purpose of the study was to assess revegetation aspects of programs developed pursuant to the Surface Mining Control and Reclamation Act of 1977 (SMCRA)--namely, the Federal Permanent Regulatory Program of 1979, and various State laws, regulations, and technical guidelines--which implement the policies and requirements of SMCRA.

This report specifically addresses the collection and use of vegetation baseline and revegetation evaluation data, their use in the permitting process, the status of research and innovation in revegetation technology, and issues pertaining to revegetation arising from the Federal and State regulatory programs. The work was an office overview aimed at identifying problems and questions rather than providing solutions and answers concerning revegetation of surface coal mined lands in the study area. It was carried out from December 1984 through March 1985 with revisions made in July and August 1985.

The study area consisted of five western coal-producing states: Colorado, Montana, New Mexico, North Dakota, and Wyoming. This study focuses on revegetation of native rangelands and wildlife habitat because these are the predominant land uses in the study area and pose the major revegetation difficulties. In contrast, the less extensive land uses of tame pastureland and cropland can be readily re-established in the study area if proper procedures are used.

It should be noted that areas revegetated since SMCRA were quite young at the time of this study (usually 1-6 years old). Therefore, only short-term success could be evaluated at the time of this report because long-term results do not yet exist.

EXISTING VEGETATION DATA

Baseline Information

Baseline data are used to establish revegetation performance standards which are based upon quantitative evaluations of vegetation parameters. Baseline vegetation studies are required to include preparation of a vegetation map and quantitative sampling of biomass production, cover, and woody plant density. Which of these parameters must be sampled is dependent upon land use. Lifeform and species diversity is typically calculated from cover or production data.

For native rangeland and wildlife habitat land uses, vegetation data currently exist from three major sources: (1) range management evaluations of grazinglands by Federal agencies, notably the Soil Conservation Service (SCS), Bureau of Land Management (BLM), and U.S. Forest Service (USFS); (2) research projects by government agencies and universities; and (3) baseline vegetation inventories accompanying permit applications by coal companies.

Federal range management data are abundant for the study area although data collection techniques have generally been geared for relatively cursory examination of large tracts. SCS year-site estimates of production are the most reliable and extensive of these types of data, but their utility in the regulatory framework is diminished by a tendency to emphasize unrepresentative stands of "climax" vegetation and by a lack of adjustment for climatic fluctuations. Research data are usually collected with intensive sampling techniques, but the techniques vary widely and only a minor fraction of mining lands in the study area have been studied. Thus, neither of these sources of existing information is sufficient to meet the requirements of objectivity, repeatability, and statistical adequacy demanded by the regulatory process.

Mine permit applications include considerable amounts of baseline data, collected more intensively than government range management evaluations. However, variable methods and worker skills limit the value of these data as possible substitutes for site-specific studies. A basic problem with using any data that are not site specific is that local vegetational variability is sufficiently great that standards based on data from neighboring localities may provide for revegetation performance standards significantly higher or lower than appropriate.

Revegetation Information

With a few exceptions, revegetation monitoring data collection has been a low priority. Variability in intensity and procedures of collecting, analyzing, and reporting revegetation monitoring data greatly limits their value for advancing the knowledge of the effectiveness of varying revegetation techniques for both industry and regulators. However, monitoring data are useful for identifying revegetation problems and documenting differences in success of techniques and materials used at individual mines. Submittal of standardized, more detailed monitoring data would benefit mining companies by facilitating the exchange of information on how best to deal with a specific problem.

Revegetation research data have been applied with good short-term results in coal mine revegetation, but it is too soon to judge the long-term results. Data on test grazing of reclaimed native rangelands are not yet available, and with the exception of Montana little testing has occurred to date. Summaries of revegetation research and mine innovations are presented in tables in the report. Two important points emerging from this study are first, that the USFS has been the government agency most directly involved in revegetation research; and second that research activities have decreased dramatically over approximately the past 5 years.

Some recently developed technologies and strategies show promise for reducing the difficulty of achieving some or all of the revegetation performance criteria on native rangelands and wildlife habitat. These include direct haul or "live" topsoiling, new plant materials, reduced competition between lifeforms, reduced fertilization, grassland management, improvements in shrub establishment, new mulching techniques, reduced irrigation, landscape diversity strategies, and improved revegetation equipment.

Predicting revegetation success of native rangelands and wildlife habitat is not highly reliable at present, because the long-term success of the newest revegetation technologies cannot yet be demonstrated. Only one serious attempt at using a model to predict revegetation success has been pursued in the study area, but it was based on results of earlier technologies in areas reclaimed under pre-SMCRA requirements. In effect, the only valid tool for prediction at present is to consider the results obtained using the most recent technologies at nearby mines having similar conditions. This case-by-case approach is essentially the technique employed by State regulatory personnel in making their "Technical Evaluation and Analysis" of a permit application.

EVALUATING REVEGETATION SUCCESS

Background

Evaluation of revegetation success at the end of the 10-year liability period will be based on the revegetation performance standards in each of the states. Revegetation performance standards include three major aspects: (1) vegetation parameters, such as production, cover, woody plant density, and lifeform or species diversity; (2) revegetation standards systems, such as reference areas or control areas, which are used to establish the performance standards and to adjust them for climatic fluctuations; and (3) statistical standards in both the vegetation and revegetation sampling programs. Variations in the standards among the regulatory programs are closely tied to postmining land use.

Croplands have the same performance standards throughout the study area (i.e., production), as do pasturelands except for cover and lifeform or species diversity requirements in North Dakota (where agricultural land uses are more prevalent). Native rangeland performance standards are similar in the five states, and include cover, production, lifeform or species diversity, and woody plant density. (The latter standard is omitted for North Dakota where rangeland is mostly shrubless.) Wildlife habitat standards differ: New Mexico and North Dakota require woody plant density and cover, but not production, while Colorado, Montana, and Wyoming require that the wildlife habitat standards address the same parameters as native rangeland.

Test grazing of native rangeland and pasturelands is required in all states except North Dakota.

Required Revegetation Parameters

Final evaluation of revegetation has not yet occurred in the study area because the 10-year liability period is still in effect for even the earliest post-SMCRA revegetation efforts. However, available monitoring data provide a limited amount of current information.

Cover and production standards have proven fairly easy to attain, although increased reliance on diverse native species (rather than a few aggressive introduced species) has often decreased the margin by which reclaimed area cover and production exceeded original (premining) levels. Success has been especially good in northern parts of the study area and mountainous portions of Colorado, but even relatively unfavorable areas of southwestern Wyoming and northwestern New Mexico have shown the ability to support successful re-establishment of cover and production.

Woody plant density standards were not being readily attained with earlier shrub planting techniques, and this parameter was therefore a source of concern. Problems continue in certain parts of the shrub-steppe ecosystems, but density standards negotiated by individual mines and state regulators are being approached at many locations by combinations of direct haul topsoiling, techniques for reducing competition from aggressive herbaceous species, and a shift toward clustering plantings in the most favorble sites rather than attempting uniform site-wide plantings.

The woody plant density performance standard has also been an area of concern, because many ranchers and range managers feel that premining shrub densities were too high. This often has resulted from prolonged overgrazing. On the other hand, woody plants can provide important shelter and food resources for wildlife as well as other ecological benefits. The contradictory situation may occur in which a mine site must be revegetated to shrub-grassland, while adjacent tracts are having the same shrub species (especially big sagebrush) killed or thinned as part of "range improvement" programs. Acknowledgment of excessively high pre-mining woody plant density by industry and regulators is apparent in some cases where standards are negotiated below pre-mining levels.

Problems in achieving the lifeform and species diversity performance standard center on the tendency for a few aggressive cool season grass species to outcompete less aggressive species and hence to reduce diversity. New planting techniques have ameliorated the problem somewhat, but achieving lifeform or species diversity remains the performance standard that many reclamation specialists feel will be hardest to meet.

Also of concern is the lack of consensus on how to define, measure, or judge revegetation success in terms of lifeform and species diversity. There is a consensus in the scientific community that diversity is an important ecological measure. The vegetational diversity of an area enhances soil stability and long-term survival of the plant community and provides the basis for supporting diverse wildlife populations throughout the year. A numerical index approach to diversity is used by some mines, but the values are non-intuitive and do not necessarily reflect desirabe species composition. The Motyka/Bray-Curtis similarity index has some advantages over the Shannon-Weaver numerical index. Use of a lifeform/relative cover approach, based on the number of species in specified lifeform categories by vegetation type, has become more widespread than purely numerical indices.

An issue closely related to that of lifeform and species diversity is the use of introduced species on native rangeland and wildlife habitat. Introduced species are typically easier to establish than native species, and thus are especially valuable for initial stabilization of replaced soils. However, many introduced species have the disadvantages of doubtful permanence, relatively low value to wildlife, and a tendency to limit diversity because of their aggressiveness.

Revegetation Standards Systems

Revegetation standards systems include (1) unadjusted baseline--use of predisturbance vegetation data collected during one growing season with no inherent adjustment for climatic variation between years; (2) control areas--small areas representative of affected area vegetation types used to "adjust" the baseline data levels for climatic fluctuations; (3) reference areas--similar to control areas except that once "comparability" with the affected area vegetation is shown, the reference area becomes the standard; (4) historic record--premining data collected over a period of several growing seasons to bracket the "normal" range of climatic fluctuations; and (5) technical standards--postmining levels of the various parameters set from regional data or negotiation, with no adjustments for climatic fluctuations.

The primary advantage of control areas and reference areas over unadjusted baseline data and technical standards are that the former adjust for climatic fluctuations. However, it is questionable whether small areas (2-3 acres) accurately mirror the average fluctuations in affected area vegetation covering hundreds or thousands of acres. Thus, some doubt remains s to whether fair or reasonable standards will result from the use of control areas and reference areas. One possible solution to this is the "extended reference area" concept being used at one mine in Wyoming and one in Colorado. The historic record approach, with data collected over a period of several years, overcomes the representativeness problem concerning areal extent, but it only reflects the range of values occurring during the historic record period and the statistical details of its application have not been fully explored.

Another potential solution to the problem of establishing and maintaining performance standards is to improve technical standards. Possible data bases for these standards would be SCS year-site data corrected for annual precipitation or the body of existing data from previous mine baseline studies. However, either basis is fairly sound only for production data. In fact, the only widespread use of technical standards has been in negotiated woody plant density and diversity performance standards, as noted above.

Statistical Methods

Statistical methods used in the application of quantitative performance standards to surface coal mine revegetation have been a topic of controversy. The debate has centered on two aspects: (1) statistics for determining sample adequacy, and (2) statistics for determining revegetation success (or comparability between reference areas and affected areas).

State regulations or guidelines concerning sample adequacy have generally resulted in sample sizes that are very high, generally exceeding levels considered adequate for academic research. Consequently, many states have instituted ceilings on sample size so that absurd numbers of samples are not taken. The comparison of affected (or revegetated) area values to reference area values typically has been done by testing for "sameness" with a statistical method designed to test for "difference." This backwards use of the statistical tool is awkward and has some negative results.

Other Vegetation Parameters

In our opinion, three additional vegetation parameters need to be evaluated that have not yet been adequately considered in the regulatory process in all states: landscape diversity, test grazing, and permanence.

"Diverse" vegetational cover, as required by SMCRA, has been interpreted as referring primarily to lifeform or species diversity. However, equally important for many wildlife species is landscape or plant community diversity. At least three factors have worked against widespread adoption of greater landscape diversity in coal mine reclamation. First, requirements for approximate original contour have generally resulted in gently undulating terrain with little topographic variety. Second, requirements for uniform topsoil depths over the regraded surface further homogenize site conditions. At some localities, variations in topsoil depth, even to the point of no topsoil in areas intended for re-establishment of shrub communities, may be entirely appropriate. Third, the revegetation programs at some mines have been kept as simple as possible to minimize costs. In spite of such factors, several mines in the study area are already involved in programs to recreate landscape diversity.

Test grazing, although a performance standard for grazinglands in four states, has thus far received little attention outisde Montana. Consideration needs to be given soon to what should or should not be required concerning specificity of grazing plans, data collection (in terms of assessing the response of vegetation and soils to grazing pressure), and timing of data submission to the regulatory authority.

The SMCRA requirement for "permanence" of the vegetation cover could be inferred from quantitative indicators that could be included in the testing of revegetation success. At present, only Montana specifically addresses permanence, which is measured as the proportion of species that are native. A major uncertainty in the revegetation of western surface coal mines is related to permanence. The uncertainty is the re-establishment of ecosystem function, which in addition to the quantitative performance standards involves re-instituting nutrient cycles and energy flow. Also of interest in the rehabilitation of ecosystems is the degree of perturbation they can absorb without a major shift in species composition. Very little is known of this property in reclaimed lands. These aspects of re-established ecosystem function are unaddressed by existing performance standards.

RESEARCH

Although research and innovation have resulted in considerable progress toward achievement of revegetation performance standards, continued research is greatly needed to address remaining uncertainties, particularly concerning achievement of revegetation permanence, grazing capacity, and diversity, as well as methods of adjusting cover and production performance standards for the effects of year-to-year climatic fluctuations. Continued improvements in revegetation technology depend upon continuing studies of the long-term productivity and stability of mine sites already revegetated, and the widespread dissemination and discussion of such information. Sites with problem soils or extremely low or erratic precipitation should also be a high priority. In terms of specific technologies, we expect one of the more fruitful topics for native rangeland and wildlife habitat to center on maximizing the effectiveness of soil handling so that the biologically most active surface soil layers are preserved, which would facilitate long-term revegetation success.

OTHER ISSUES

Three other issues in addition to the primary revegetation topics are discussed in this report. These are the use of design standards versus performance standards, how the regulatory processes affect innovation at the mines, and the phasing of bond release. Concerning the third point, as little as 15 percent of the bond may remain at the conclusion of revegetation testing--an amount possibly insufficient for corrective actions where defects in overburden or topsoil are responsible for unsuccessful revegetation.

SECTION 1.0

INTRODUCTION

1.0 INTRODUCTION

1.1 OBJECTIVES

The purpose of this study was to assist the Office of Technology Assessment (OTA) in assessing the procedures and achievement of revegetation under the Federal Surface Mining Control and Reclamation Act of 1977 (SMCRA), the Federal Permanent Regulatory Program of 1979, and pertinent State laws and regulations. This report addresses (1) existing vegetation data, methods of sampling premining vegetation, and techniques for predicting and evaluating revegetation success at surface coal mines in the western United States; (2) the use of specific types of vegetation data and revegetation evaluations in the regulatory process; (3) the status of innovation and research in revegetation and the implementation of resultant technology toward achievement of performance standards in the study area; and (4) current vegetation and revegetation issues at surface coal mines in five western states: Colorado, Montana, New Mexico, North Dakota, and Wyoming. Companion reports address the related topics of soils and overburden (Walsh & Associates 1985), wildlife (Cedar Creek Associates 1985), and hydrology (Western Water Consultants, Inc. 1985).

The 1979 Permanent Regulatory Program implementing SMCRA was revised in 1982-83, although the revisions are currently being litigated before Judge Flannery in U.S. District Court in Washington, D.C. The 1979 regulations formed the basis for the current State programs and influenced the direction of western surface coal mine revegetation and therefore are emphasized in this report. Changes in the regulations that could affect revegetation and are at issue in the present litigation are briefly discussed in Section 2.7. This report does not address abandoned mine lands, mines located on Indian lands, and questions of land use aside from the appropriateness of specific data collection techniques or revegetation success standards. Mines having Federal coal were emphasized during the study. It also should be noted that the study was an overview of the status of revegetation at surface coal mines in the study area, and therefore focused on identifying problems and questions rather than providing solutions and answers. Finally, the study dealt mainly with revegetation of native rangelands and wildlife habitat, for two reasons: first, only in North Dakota do improved pastureland and cropland comprise a substantial part of surface coal mined lands. Second, successful revegetation of tame pastureland and cropland is readily attainable, and further improvements are more likely to stem from changes in the handling and treatment of soils and overburden than from changes in revegetation technology per se.

1.2 BACKGROUND

In 1984, OTA reviewed the environmental protection aspects of the Federal Coal Leasing Program because of controversies arising from the 1982-1983 changes in the implementing regulations. The present study represents OTA's response to a request from the Chairman of the House Interior and Insular Affairs Committee for information building upon the 1984 study to evaluate environmental protection under SMCRA. This work focuses on the permitting, operation, and reclamation stages of coal mining. The two principal goals of SMCRA are to (1) protect the Nation from adverse social and environmental impacts related to the mining of coal, and (2) ensure the production of coal as an essential part of the Nation's energy supply. SMCRA created the Office of Surface Mining (OSM) as an implementation and enforcement agency and authorized the states to adopt their own implementation and enforcement programs in accordance with SMCRA.

The five states in the study area all have approved state programs. Their regulatory authorities are: Colorado Division of Mined Land Reclamation (CMLRD), Montana Department of State Lands (MDSL), New Mexico Energy and Minerals Department (NMEMD), North Dakota Public Service Commission (NDPSC), and Wyoming Department of Environmental Quality (WDEQ). The Office of Surface Mining (OSM) has an overview responsibility to ensure that the various State programs are established and run in full compliance with the Federal program.

1.3 RESEARCH METHODS AND SOURCES

The major objective of this study was to synthesize a comprehensive but not exhaustive overview of revegetation in the study area. Time limitations did not allow a uniformly intensive study of all active surface mines with Federal coal in the five-state region.

Information gathered and analyzed during the study included (1) mine permit applications submitted under State programs developed pursuant to SMCRA; (2) relevant State and Federal decision documents; (3) results of interviews with State and Federal regulatory personnel, reclamation specialists at coal companies, representatives of environmental groups, and researchers at a variety of agencies and institutions (see Appendix A for a full list of persons contacted); (4) published and unpublished literature and legal documents; and (5) prior experience of the authors.

Senior authors of this report were Dr. David L. Buckner of Western Resource Development Corporation (WRD) and Dr. Jane E. Bunin, an independent consultant. Both senior authors are plant ecologists and reclamation specialists with thirteen years of professional experience in the study area. Junior author and technical editor for the report was Dr. Allen B. Crockett of WRD, an ecologist and attorney with eleven years of professional experience in the region.

1.4 PHASES OF STUDY

Four basic phases of study were carried out between late December 1984 and March 1985. These were (1) overview, (2) case studies, (3) technical analysis, and (4) issues analysis.

The first two phases were information-gathering tasks that utilized checklists and questionnaires to tabulate the existing information and ensure standardization of methods and results. Information gathered during Phase One included (1) the status of existing vegetation data in the five-state study area (including type of data, geographic source, scientific source, location and availability of data, and date of field acquisition), (2) techniques used to collect premining and postmining vegetation data, and

(3) techniques used to predict impacts or evaluate revegetation success (including methods, scientific or technical assumptions, regulatory use, and appropriateness).

Detailed case studies were undertaken in Phase Two in order to more closely examine the details of the regulatory and technical processes leading to revegetation. These case studies examined techniques employed in collecting baseline vegetation data, establishing and adjusting revegetation standards, implementing the revegetation plan, and monitoring or evaluating revegetation success at each mine selected. This was accomplished by examining permit application documents and correspondence on file with OSM and the State regulatory authorities and interviewing regulatory and mining company personnel.

During the literature review task of Phase Two, the vegetation portion of the permit application for each mine was examined for the following information: time of baseline data collection; sample design and methods for determining cover, production, woody plant density, and species diversity; methods of establishing and adjusting the revegetation standards; and methods of statistical analysis. The reclamation plan portion of each application was reviewed to determine the revegetation techniques, methods for evaluating revegetation success, and monitoring programs proposed by the various mines. Also reviewed were status and monitoring reports compiled by the regulatory authorities and annual reports submitted by the coal companies.

During the interview portion of Phase Two, information was obtained on the status of revegetation performance standards, the usefulness of particular revegetation techniques, the application and success of innovative techniques, and details on the permitting process.

It should be noted that revegetation conducted after 1979 under SMCRA regulations is quite young (1-6 years old). Therefore, given the liability period of 10 years, no areas have yet been subject to final determination of revegetation success. Furthermore, the "state of the art" in revegetation is changing rapidly. The currently most advanced techniques have been implemented only within the last few years, and their effectiveness cannot be determined for several more years. Thus, results of revegetation to date reflect a mix of older technologies and very young stages of newer technologies. Note that no judgments are made about quality or ultimate success of revegetation.

Phase Three (technical analysis) addressed the applicability of existing data and techniques to the process of establishing performance standards and judging revegetation success. The result of the Phase Three effort is a discussion of various techniques used to quantify premining vegetation, establish and adjust revegetation performance standards, and test revegetation success, and uncertainties inherent in the process of setting and applying revegetation success standards. Achievements to date in restoring vegetation cover, production, woody plant density, and diversity also were reviewed in Phase Three.

Phase Four (issues analysis) addressed key issues and areas where improvement is needed, and uncertainties about the long-term response of revegetated areas. These uncertainties may be reduced through an understanding of the ecology of artificially created plant communities. Therefore, Phase Four also identified research topics relating to the resolution of these uncertainties.

SECTION 2.0

OVERVIEW

2.0 OVERVIEW

2.1 ENVIRONMENT OF THE STUDY REGION

2.1.1 Vegetation

In general, the goal of revegetation in the five-state study area is re-establishment of plant cover, production, and diversity equivalent to that which existed on the site prior to mining. Exceptions to this goal are mines where a change in land use has been permitted or where the premining vegetation was severely abused and thus could not serve as an acceptable standard for evaluation of revegetation success.

The range of natural vegetation within the coal-producing portions of the five-state study region is broad, including desert, grassland, shrub-steppe, mountain brush, broadleaf forest, and various coniferous woodland and forest types. Drainages are especially important in much of the region, because the moister conditions frequently support greater densities and diversities than drier uplands and may support plant and animal species not found elsewhere. Most of the region is dominated by natural or partially modified plant communities used concurrently for livestock grazing and wildlife habitat, with a lesser amount of medium intensity agriculture such as hayland. Only North Dakota has a significant proportion of coal lands in intensive agricultural use, such as annual grazing production.

The revegetation and permitting processes of the five states are affected by variations in the existing vegetation. For example, the desert grasslands of northwestern New Mexico present different revegetation problems from the mountain brush in northwestern Colorado, the mixed grasslands in northeastern Wyoming, the ponderosa pine woodlands of southeastern Montana, and the woody draws along drainages in North Dakota. The five-state study area has been divided into four ecological provinces on the basis of natural characteristics: Great Plains-Shortgrass Prairie, Wyoming Basin, Rocky Mountain Forest, and Colorado Plateau (Bailey 1980) (Figure 1).

Most of the surface coal mines in the Great Plains-Shortgrass Prairie Province are located in either the Grama-Needlegrass-Wheatgrass or the Wheatgrass-Needlegrass Sections. These areas include the Ft. Union and Powder River Basin coal regions of Montana, North Dakota, and Wyoming, which receive about 10-17 inches average annual precipitation. The vegetation is primarily grassland dominated by wheatgrasses (Agropyron spp.), needlegrasses (Stipa spp.), and blue grama (Bouteloua gracilis), or shrub-steppe dominated by those grasses plus sagebrush (Artemisia spp.). Variations in soils, aspect, and wind exposure can cause marked differences in plant communities over relatively short distances, creating mosaics of grassland and shrubland communities. Stands of ponderosa pine (Pinus ponderosa) occur on uplands, ridges, and north slopes within limited areas of the Great Plains-Shortgrass Prairie Province in eastern Montana and northeastern Wyoming. Throughout the Great Plains-Shortgrass Prairie province, and particularly in North Dakota, drainages may support riparian thickets of deciduous shrubs or trees. These drainages are locally referred to as "coulees" or "woody draws."

The Wyoming Basin Province includes parts of the Green River-Hams Fork coal region, which receives an average of 5-11 inches of annual precipitation. The Sagebrush-Wheatgrass Section encompasses most of the surface coal mining in the province in southwestern Wyoming. Prevalent vegetation typically consists of communities dominated by saltbushes (Atriplex spp.)

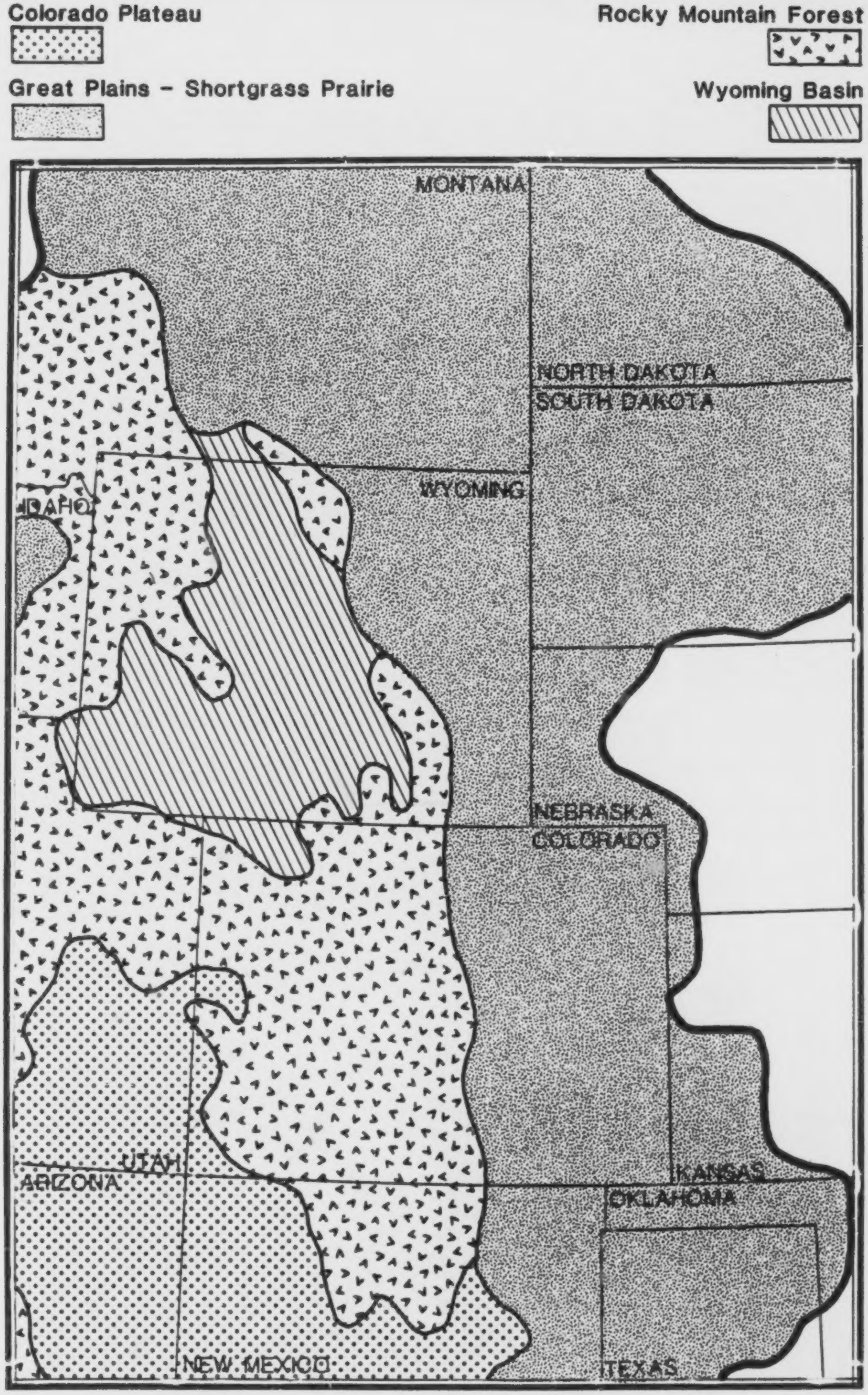

Colorado Plateau
Rocky Mountain Forest
Great Plains - Shortgrass Prairie
Wyoming Basin
MONTANA
NORTH DAKOTA
SOUTH DAKOTA
WYOMING
IDAHO
NEBRASKA
COLORADO
UTAH
ARIZONA
KANSAS
OKLAHOMA
NEW MEXICO
TEXAS

Figure 1. Location map showing major ecological provinces in the study region. Source: Bailey (1980)

on upland alkaline sites and various big sagebrush-grassland communities on more neutral uplands. Alkaline drainages are likely to contain greasewood (*Sarcobatus vermiculatus*) communities, while persistent drainages through neutral substrates may support broadleaf shrubs and trees such as willows (*Salix* spp.) and cottonwoods (*Populus* spp.).

The Rocky Mountain Forest Province includes the coal mining areas of northwestern Colorado and north-central New Mexico. In northwestern Colorado, annual precipitation is relatively high (averaging about 15-25 inches), and taller shrubs or trees dominate the vegetation. Big sagebrush (*Artemisia tridentata*) typically occupies areas with moderate slopes and soils with moderate or fine textures. Tall shrubs such as Gambel's oak (*Quercus gambelii*) and serviceberry (*Amelanchier* spp.) often form dense thickets on steeper slopes and coarse or shallow substrates. Quaking aspen (*Populus tremuloides*) occurs on deep loamy soils in sites where moisture collects. Drainages support willows and cottonwoods along with aspen and tall shrubs such as chokecherry (*Prunus virginiana*). In north-central New Mexico, where annual precipitation averages about 12-16 inches, the vegetation is dominated by open, dry woodlands of ponderosa pine, pinyon pine (*Pinus edulis*), Douglas-fir (*Pseudotsuga menziesii*), and juniper (*Juniperus* spp.).

The Colorado Plateau Province includes coal mining areas in northwestern New Mexico and southwestern Colorado, with an average annual precipitation of about 10-20 inches. These areas are dominated by the Grama-Galleta Steppe and Juniper-Pinyon Woodland Mosaic Section. Vegetation on the alkaline sites is usually of the salt desert shrub type, with saltbushes dominating. Less alkaline sites may support big sagebrush grasslands that probably are the result of overgrazing. Grama-galleta (*Bouteloua* spp.-*Hilaria jamesii*) grasslands in northwestern New Mexico represent a western extension of plains grasslands. At the higher elevations and on rocky sites, pinyon-juniper woodlands become common.

2.1.2 Environment

Soil texture, depth, and alkalinity along with site elevation, slope, aspect, and wind exposure are but a few of the site-specific factors that affect vegetation. Soils are variable and poorly developed in most of the study area. In general, only mines in North Dakota and northwestern Colorado have relatively fertile, well developed soils. A companion report discusses soils and overburden reclamation in the study area (Walsh 1985).

Climate of the five states can be characterized as semi-arid or arid continental, with highly variable precipitation and wide temperature ranges. In general, plant-available moisture is the primary limiting factor for plant growth and successful revegetation of disturbed areas, and the specific amount, form, and seasonal distribution of precipitation strongly influence plant-available moisture at particular locations (Van Epps and McKell 1978). Fluctuations in total annual precipitation are substantial, with long-term averages varying from approximately 5 inches (13 cm) to 25 inches (63 cm) in surface coal mining portions of the study area.

Plant-available moisture is typically at a maximum in late spring to early summer for most of the study area, although in northwestern New Mexico and southwestern Colorado the maximum is in mid to late summer.

Patterns of plant-available moisture and temperature together explain why cool season species dominate the central and northern parts of the study area, while warm season species prevail in the southernmost part. Cool season species carry out most of their growth before or after the heat of summer, while warm season species start and accomplish their growth at warmer temperatures. The spring precipitation maximum in most of the study area coincides with the maximum growth period of the cool season species. Similarly, the summer precipitation maximum in the southern part of the study area coincides with the maximum growth period of warm season species.

Fire and grazing are two widespread environmental factors that are strongly influenced by humans. Both factors may dramatically affect plant species presence, cover, and productivity and cause long-term changes in ecosystem function (e.g., see Wells 1965, Sims et al. 1978).

2.2 HISTORICAL PERSPECTIVE ON MINE REVEGETATION

The earliest attempts at surface coal mine revegetation in the West were undertaken from a range improvement and agronomic point of view, using rangeland and agricultural equipment and introduced plant materials. This was natural, because the stimulus for such activity was the desire to return mined land to agricultural use, generally livestock production. Species planted usually were selected from a small group of highly productive and aggressive grasses introduced to the U.S. from central Asia in the early part of this century to improve pasture forage production. These species--notably crested wheatgrass and desert wheatgrass (Agropyron cristatum and A. desertorum)--were fairly successful, even on raw spoils, in mine areas receiving more than about 10 inches annual precipitation.

Most of these early efforts were conducted in compliance with laws passed by the States--such as the Wyoming Open Cut Land Reclamation Act of

1969--which did not require topsoiling, had few if any specifications on native versus introduced species, and included no revegetation performance standards.

As environmental awareness grew during the 1970s, these laws and pursuant regulations were revised to include provisions related to topsoiling, seed mixes, and revegetation performance standards (see Table 1). This trend was reflected in SMCRA by the requirement for "a diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area. . ." and in the subsequent regulations by the establishment of performance standards for cover, production, diversity, woody plant density, permanence, and "nativeness."

This trend toward requiring the re-establishment of diverse, self-sustaining, native plant communities--rather than merely using aggressive, introduced forage species to replace lost values of cover and production as previously was typical--necessitated the development of more advanced revegetation techniques. These are described in Section 2.9.

2.3 REQUIREMENTS FOR BASELINE DATA

2.3.1 Background

Evolving concurrently with the trend toward requiring that reclamation return some semblance of the premining ecosystem structure (and, by implication, function) and not just values of cover and production, were the requirements for a baseline vegetation inventory to qualitatively and quantitatively describe premining conditions. Reviews of baseline sampling methods can be found in Cook and Bonham (1977), Chambers and Brown (1983), and Prodgers (1983), among others.

Baseline data often are useful for reclamation planning but are mandatory for evaluating revegetation success. A detailed baseline sampling program is usually necessary to establish revegetation performance standards based upon premining values of specific vegetation parameters. To establish performance standards, baseline data for areas to be mined ("affected areas") are often quantitatively compared with baseline data for corresponding vegetation types in areas to remain undisturbed ("control areas" or "reference areas"). After mining, the undisturbed areas are then quantitatively compared to the reclaimed areas in order to evaluate success, i.e., whether the performance standards have been attained.

It is informative to compare the baseline vegetation information required by the specific language of SMCRA with details of the Federal Permanent Regulatory Program of 1979. As noted earlier (Section 2.2), SMCRA specifies that the aim of revegetation at coal mines is to establish "a diverse, effective, and permanent vegetative cover of the same seasonal variety native to the area [and which is] at least equal in extent of cover. . . ." Both the 1979 and 1984 Federal regulations mention not only the establishment of diverse vegetation of comparable cover and seasonal variety, but also add performance standards for production and woody plant density, statistical standards for evaluating revegetation success, and a requirement for the use of reference areas or approved technical standards as the basis of judging the achievement of the performance standards. Also, a vegetation map is required as part of the permit application process. Thus, the requirements for baseline vegetation data arise in large part from the Federal Permanent Regulatory Program's system of judging revegetation success.

While the ultimate mandate for baseline data collection is included in SMCRA, each of the five states has its own legislation and rules or regulations controlling baseline data collection at surface coal mines (Table 1). The legal citations of the State acts and regulations are provided in the references section of this report (Section 6.0). Only Montana and Wyoming have written guidelines for vegetation baseline studies at present. The Montana DSL is in the process of reviewing many aspects of its data requirements and recommended methods, and the Colorado and New Mexico regulatory authorities currently are developing guidelines. The North Dakota PSC has no plans for formal guidelines, although they issue technical memoranda. Agency personnel in North Dakota feel that this less formal approach to guidelines gives them more flexibility in developing revegetation standards that deal with the wide range of situations represented by the diverse land uses in that state.

In assessing the baseline vegetation requirements of the five states in the study area, it was necessary to (1) review the legislation, regulations, and guidelines of the various states; (2) examine the types of data collected and techniques employed, as indicated by the vegetation portions of the permit application documents; and (3) interview personnel at the regulatory authorities and mining companies about practical application of the various regulatory programs.

2.3.2 State Requirements as Related to Land Use

Most of the baseline data collection requirements incorporated into State regulations and guidelines are directed toward sampling of lands used as native rangeland and wildlife habitat, with subsets of these data required for other land uses such as pastureland and cropland. Native rangeland and wildlife habitat comprise by far the greatest portion of mined lands in the study area.

Sampling requirements for native plant communities, especially native rangeland, are summarized in the following subsections and Table 1. Variations in sampling design associated with other land uses are described where appropriate in the following subsections.

2.3.2.1 Vegetation Maps. Maps depicting the distribution and relative areal extent of vegetation types (or other map units) in the permit area are required for all land use categories by each of the five states. This helps both in the qualitative description of the vegetation types and the random or systematic location of quantitative sampling sites for cover, production, or woody plant density in both the affected (mined) and unaffected (e.g., reference) areas.

The quality of a vegetation map depends upon the appropriateness of the mapping units selected, the skills of the observer, and the map scale. Acceptable vegetation map scales in the study area range from 1" = 400' (1:4800) to 1" = 2000' (1:24,000). Most permit applications have used detailed scales such as 1" = 400' or 1" = 500'.

Mapping units used in the study area normally are either range sites or vegetation types. Range sites, the units most commonly used by Federal agencies such as the U.S. Soil Conservation Service (SCS), U.S. Bureau of Land Management (BLM), and U.S. Forest Service (USFS), represent the potential natural ("climax") vegetation in an area, based in large part on soils and climate. These are broad units, usually mapped by the SCS at a scale of

TABLE 1

SELECTED CURRENT REQUIREMENTS FOR VEGETATION BASELINE DATA BY STATE*

	CO	MT	NM	ND	WY
Vegetation Mapping	Required in all states				
Range Sites		R	Z	R[f]	
Vegetation Types	R	R	R	R[g]	R
Sale	R,1" = 2000' X,1" = 500'	R,1" = 400' for veg type map	X,1" = 500'	R,1" = 400' for both maps	X,1" = 400'-700'
Cover Data	Required in all states for native rangeland and wildlife habitat and in ND for tame pastureland				
Absolute Cover	R	R	R	R	R
Relative Cover	Z	X		Z	X
Quadrat Estimation	Z	X	X		X
Cover Classes	Z	Z	Z	Z[g]	Z
By Percent	Z	X	Z		Z
Line Intercept	Z[a]	X[c]	Z		X[a]
Point Intercept	Z		Z	Z	X
Production	Required in all states for native rangeland, cropland, and pastureland				
Herbaceous	R	R[d]	R	R	R
Woody	X[b]	R	X[e]		
Clipping	X	R	X	X	X
Quadrat Size	variable	X,0.5 m^2	variable	Z,often 0.25 m^2	Z,0.5 m^2
Doubling Sample	Z		Z	Z	
Shrub Density	Required in all states for wildlife habitat and in CO, MT, NM, and WY for native rangeland				
Shrubs	R	R	R	R[g]	R
Subshrubs		R	R	R[g]	X
Quadrats & Belt Transects	X	X	X	Z[g]	X
Plotless Samples	Z				

TABLE 1 (cont.)

	CO	MT	NM	ND	WY
Diversity	All states require collection of data that can be used to calculate species/lifeform diversity for native rangeland and wildlife habitat				

Symbols:
R = required by state regulatory authority; law, rule, or regulation.
X = preferred or recommended by state regulatory authority; includes written guidelines (MT and WY) which tend to be viewed with the same weight as requirements
Z = not recommended but accepted by state regulatory authority.

Superscripts:
a = for shrubs only
b = when also wildlife habitat
c = for trees and shrubs only
d = by lifeforms only
e = for palatable species only
f = for native grassland only
g = for woodland or wildlife habitat only

1:24,000 or less detailed (Figures 2 and 3). BLM and USFS range sites are often subdivided into map units that reflect the existing stage of succession and the effects of management or land use practices. Mapping by the USFS has been based primarily on either range sites or timber types, although this practice has recently been complemented by the use of plant associations or "habitat types" (sensu Daubenmire 1956) which represent units of climax vegetation. Vegetation types, widely used in academic research as well as mine baseline studies, are based on the existing vegetation without reference to the potential or climax composition (Figures 4-6).

2.3.2.2 Production. This parameter refers to the amount of above-ground plant tissue (standing crop or biomass) produced during the current growing season. To a large extent, this controls the "carrying capacity" for livestock and some wildlife species. The standard technique for estimating production is to clip (harvest) the current year's above-ground growth, by species or lifeform, within circular or quadrangular plots (Figure 7). Clipping usually is done late in the growing season, at approximately the time of peak standing biomass. The clipped materials are oven-dried and weighed, and the values used to estimate the production per unit area (e.g., pounds per acre, grams per square meter) by species or lifeform for each mapping unit. Another production method little used in baseline studies is called double sampling, in which current year's above-ground biomass is visually estimated in all plots, with clipping conducted in a few of the plots to calibrate the visual estimates.

Production requirements in the five states are relatively standardized, except that (1) production data are not required for lands designated solely

Figure 2. Excerpt from an SCS range site description.

SHALLOW LOAMY (SwLy)
10-14" Northern Plains
Correlated Range Site No._____

RANGE SITE DESCRIPTION

A. PHYSICAL CHARACTERISTICS

1. Physiographic Features

This site will usually occur on steep slopes and ridge tops, but may occur on all slopes. Elevations range between 3,800 feet and 5,100 feet.

2. Climatic Features

(See attached climate description)

3. Native (climax) Vegetation

a. The climax plant community is dominated by midgrasses. Potential vegetation is about 80% grasses and grass-like plants, 10% forbs and 10% woody plants.

b. Major plant species and percentage of the total plant community by air-dry weight:

SPECIES	PERCENT
Grasses and Grass-like Plants	
Rhizomatous wheatgrasses	5-15
Western wheatgrass	
Thickspike wheatgrass	
Bluebunch wheatgrass	25-50
Needleandthread	5-10
Little bluestem	5-10
Blue grama	5-10
Threadleaf sedge	5-10
All following Grasses and Grass-like Plants [eleven species listed]	5-15*
Forbs	
All following forbs [twenty species listed]	5-10*

SHALLOW LOAMY (SwLy)
10-14" Northern Plains

Figure 2 (con't.)

Woody Plants

Winterfat	T-5
All following Woody Plants [five species listed]	5-10*

*Of plants in these groups no more than 5% of any species is allowable in the potential plant community

c. Approximate percent ground cover -- 15-25 percent.

d. As ecological condition deteriorated, blue grama and threadleaf sedge become more dominant. Species most likely to invade this site are broom snakeweed, cactus and annuals.

[etc.]

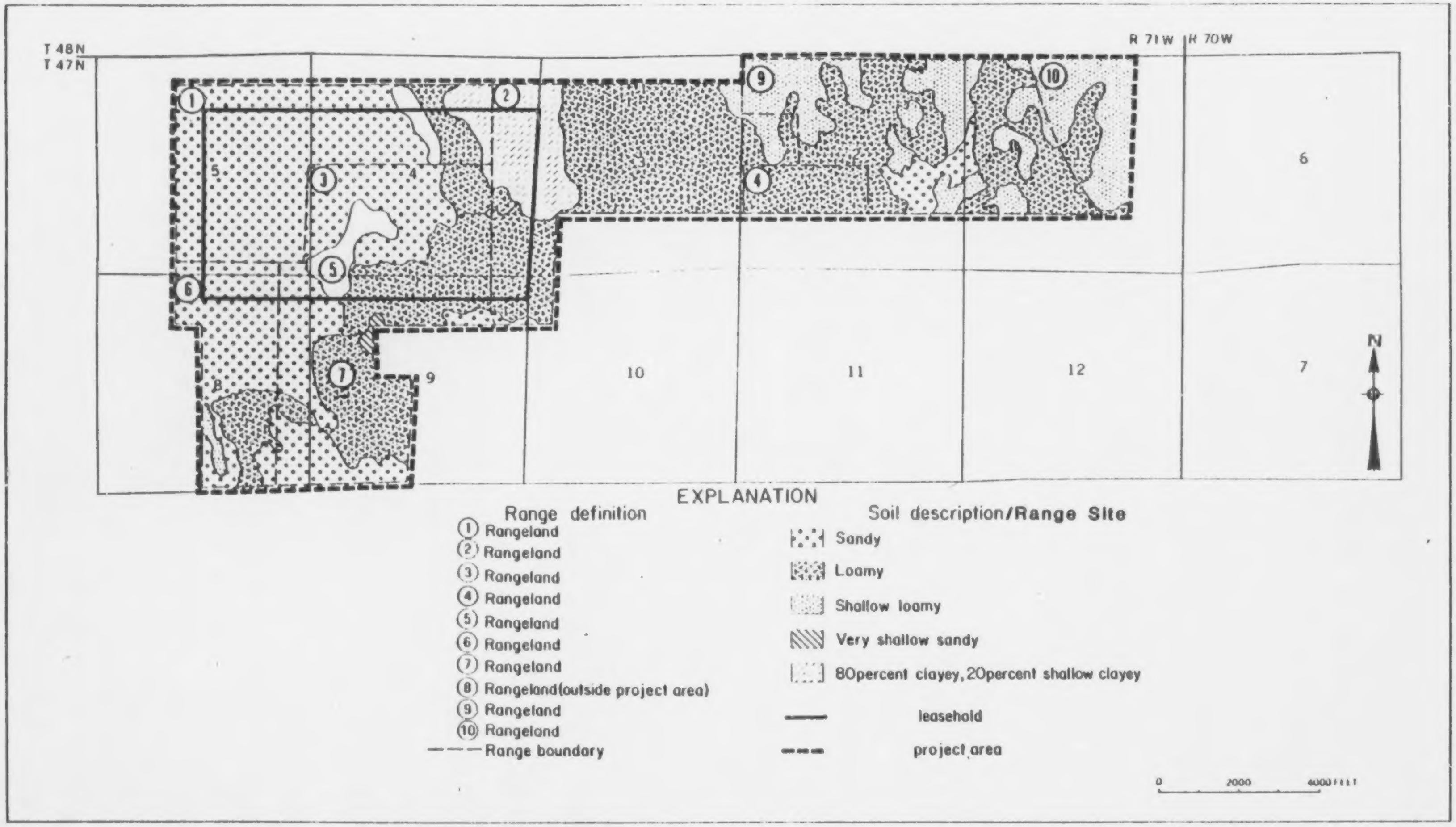

T 48N
T 47N
R 71W
R 70W
①
②
③
④
⑤
⑥
⑦
⑨
⑩
4
5
6
7
8
9
10
11
12
N
EXPLANATION
Range definition
① Rangeland
② Rangeland
③ Rangeland
④ Rangeland
⑤ Rangeland
⑥ Rangeland
⑦ Rangeland
⑧ Rangeland(outside project area)
⑨ Rangeland
⑩ Rangeland
Range boundary
Soil description/Range Site
Sandy
Loamy
Shallow loamy
Very shallow sandy
80percent clayey, 20percent shallow clayey
leasehold
project area
0
2000
4000 FEET

Figure 3. Range site map for an area of the Northern Great Plains. Note emphasis on soils.

Figure 4. Excerpt from a vegetation type description.

SAGEBRUSH GRASSLAND

Sagebrush Grassland is by far the most extensive vegetation type, occurring on all the upland portions of the permit area (3,096 acres). Wyoming big sagebrush was most abundant on deeper, finer soils and least abundant on sandy soils. It was present in slightly over half of the sample cover plots (56 percent frequency). Other species occurring in more than half of the plots were fringed sage, prairie junegrass, needle-and-thread, blue grama, Japanese brome, sixweeks fescue, woolly plantain, and ground lichen.

Cover

Perennial graminoids provided the greatest cover (30.7 percent) of any life-form. Cool season graminoid cover was 22.2 percent, while warm season graminoid cover was 8.5 percent. The most abundant cool season species were prairie junegrass (4.3 percent cover) and needle-and-thread (9.0 percent cover). Other significant cool season graminoids were streambank wheatgrass, western wheatgrass, threadleaf sedge, and green needlegrass. Minor species present included thickspike wheatgrass, bluebunch wheatgrass, Douglas sedge, sun sedge, needleleaf sedge, Canby bluegrass, mutton bluegrass, and Sandberg bluegrass. Blue grama (7.3 percent cover) comprised nearly all of the 8.5 percent cover of warm season grasses. Contributing the remainder were red threeawn, prairie sandreed, stonehills muhly, and little bluestem.

Annual graminoids comprised 7.0 percent cover, nearly equally divided between Japanese brome, cheatgrass, and sixweeks fescue.

Shrubs, subshrubs, and cushion plants contributed less than half as much cover (14.6 percent) as perennial graminoids. With 8.9 percent cover, Wyoming big sagebrush was the major species; fringed sage (3.6 percent cover) was the only other substantial contributor. Minor species included Hooker sandwort, silver sagebrush, Gardner saltbush, rubber rabbitbrush, winterfat, prickly phlox, Hood's phlox, and broom snakeweed. The latter two species, although of minor cover, occurred in almost half the cover plots.

Perennial forbs totaled only 2.1 percent cover in the Sagebrush Grassland samples. The most abundant species were rose pussytoes, silverleaf scurfpea, and American vetch. Not abundant but frequently present were nodding onion, bastard toadflax, scarlet globemallow, and common dandelion. The many minor species present included western yarrow, plains milkweed, perennial ragweed, twogroove milkvetch, Pursh milkvetch, field mouseear, Engelmann fleabane, low fleabane, scarlet gaura, curlycup gumweed, narrowleaf gromwell, silvery lupine, ironplant goldenweed, cutleaf evening primrose, broomrape, narrowleaf four-o-clock, beardtongue, plains bahia, and meadow death camas.

Figure 4 (con't.)

Annual and biennial forbs accounted for 1.5 percent cover, the bulk of which (0.9 percent) was desert alyssum. Other species most frequently present were littlepod falseflax, rough pennyroyal, and woolly plantain.

A ground lichen provided 1.3 percent cover. Other cryptogams present were mosses and other ground lichens.

Plains pricklypear was the lone succulent providing measurable cover (0.4 percent).

Total absolute vegetation cover was 51.0 percent. Cover by bare soil, litter, and rock was 15.4, 33.6, and 0.0 percent, respectively.

Production

Herbaceous production in the Sagebrush Grassland vegetation type totaled 478 pounds per acre. Perennial graminoids made the largest contribution to this total with 278 pounds per acre. The largest contributors to this amount were the cool season grasses western wheatgrass, prairie junegrass, and needle-and-thread, and the warm season grass blue grama. Annual graminoids were the next largest producer with 104 pounds per acre; Japanese brome was the major part of this total. The subshrubs fringed sage and broom snakeweed produced about 69 pounds per acre, while perennial forbs and annual/biennial forbs produced about 5 and 21 pounds per acre, respectively.

Shrub Density

Density of shrubs in the Sagebrush Grassland affected area averaged 3850 stems per acre. Most of this density was Wyoming big sagebrush (3240 stems per acre, 84 percent). Silver sagebrush (430 stems per acre) and winterfat (130 stems per acre) were the only other significant contributors. Species present in very small amounts in the shrub density samples were black sagebrush, fourwing saltbush, Gardner saltbush, rubber rabbitbrush, and prickly phlox.

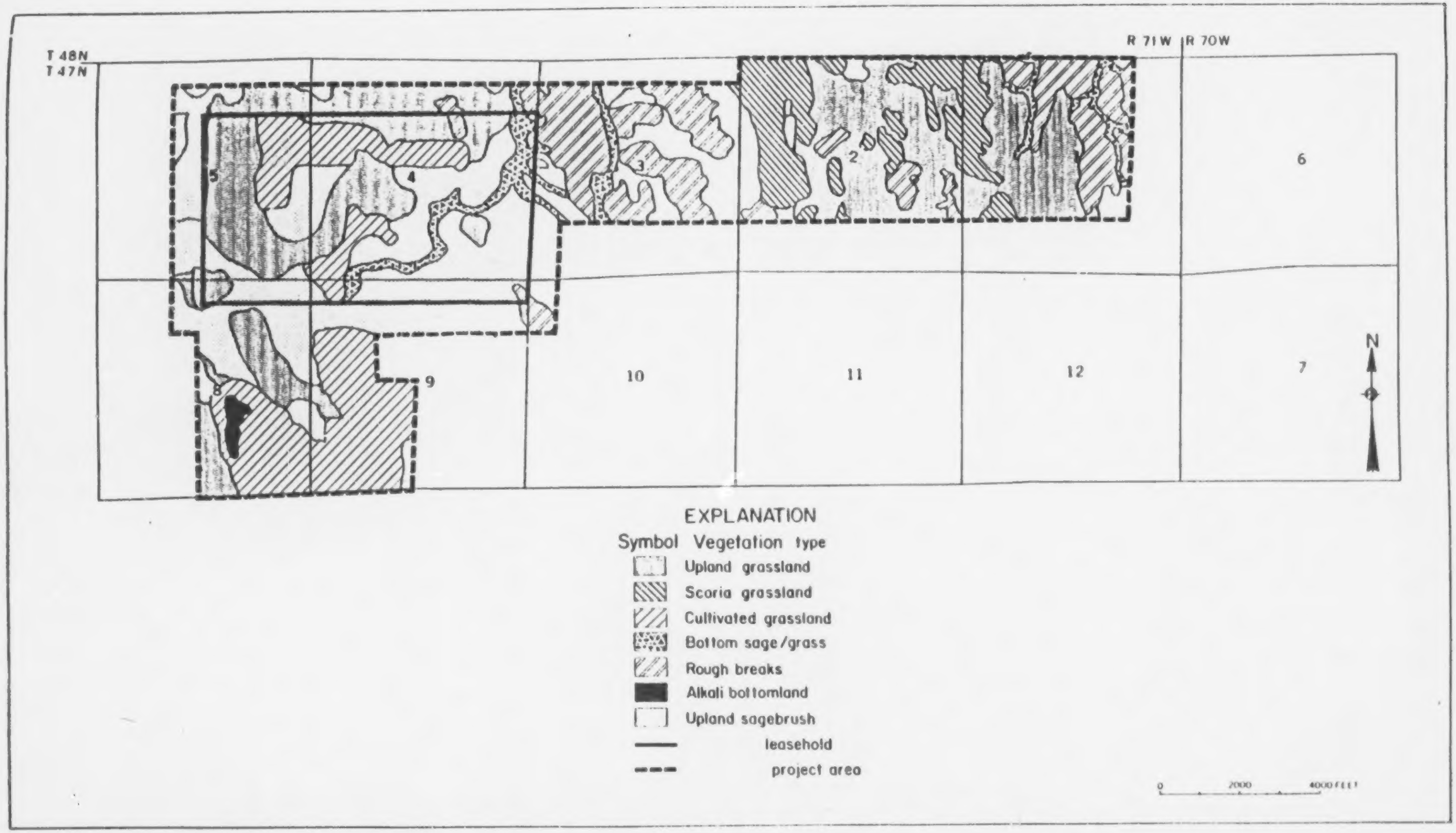

R 71W
R 70W
T 48N
T 47N
2
3
4
5
6
7
8
9
10
11
12
N
EXPLANATION
Symbol Vegetation type
Upland grassland
Scoria grassland
Cultivated grassland
Bottom sage/grass
Rough breaks
Alkali bottomland
Upland sagebrush
leasehold
project area
0
2000
4000 FEET

Figure 5. General vegetation type map for an area of the Northern Great Plains. Note emphasis on plants as well as topography and substrate, and greater detail compared to Figure 3.

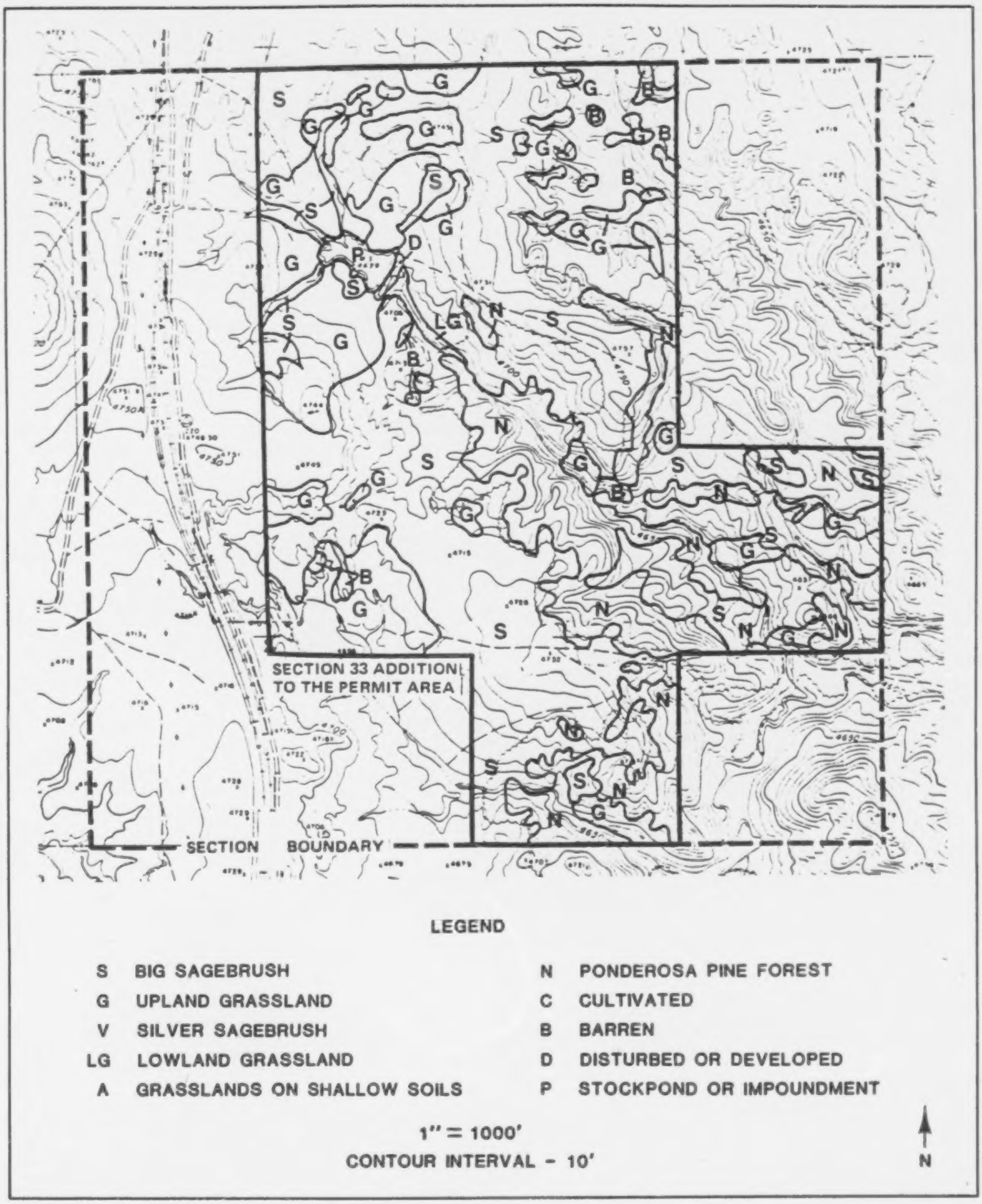

SECTION 33 ADDITION TO THE PERMIT AREA
SECTION BOUNDARY
LEGEND
S BIG SAGEBRUSH
G UPLAND GRASSLAND
V SILVER SAGEBRUSH
LG LOWLAND GRASSLAND
A GRASSLANDS ON SHALLOW SOILS
N PONDEROSA PINE FOREST
C CULTIVATED
B BARREN
D DISTURBED OR DEVELOPED
P STOCKPOND OR IMPOUNDMENT
1" = 1000'
CONTOUR INTERVAL - 10'
N

Figure 6. Detailed vegetation map from the northern portion of the study region. Note relationship to topography.

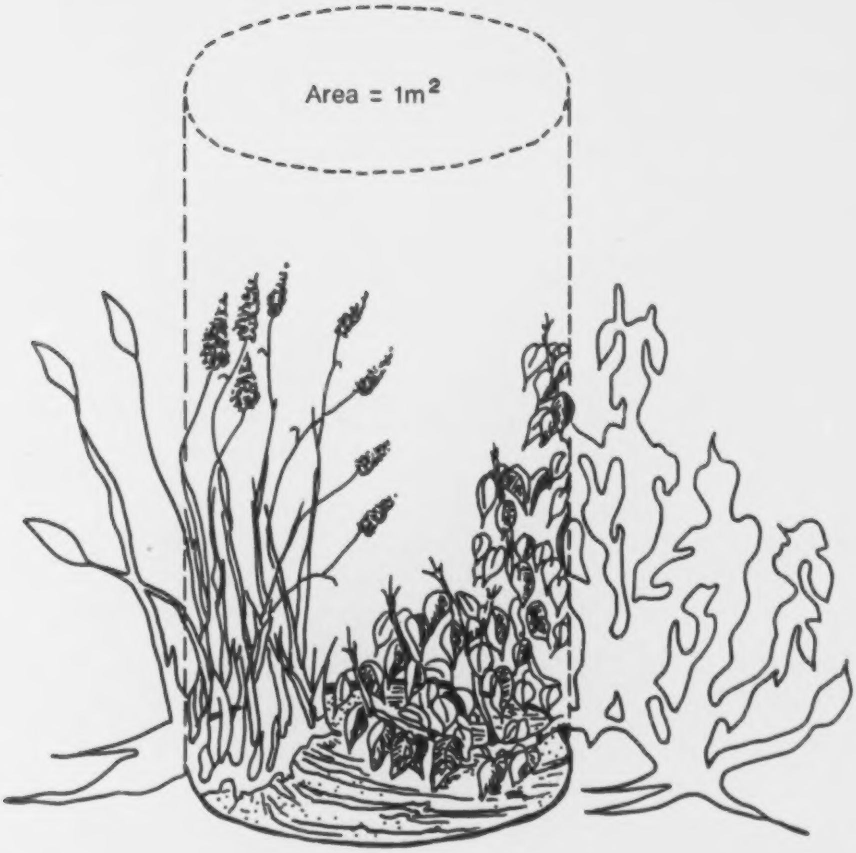


Figure 7. Graphic representation of a production sampling plot. Current year's above-ground growth within the imaginary cylinder is clipped, dried, and weighed. (from Chambers and Brown 1983)

as wildlife habitat in New Mexico or North Dakota, (2) production of croplands usually is based on yields as reported by the rancher or farmer, and (3) woody plants and annual plants may or may not be included depending on state and land use.

2.3.2.3 Cover. This term describes the percentage of the ground covered by aerial (above-ground) plant parts. Cover usually is expressed as the actual percent of the ground shielded by each plant species. This is the "absolute cover" percent value, which may range from near zero in areas with sparse vegetation, to greater than 100 percent where the plant canopies overlap. "Relative cover" is the percentage of the total vegetation cover contributed by each species and therefore totals 100 percent by definition. A species with 50 percent absolute cover actually covers half of the ground surface from an aerial view, while a plant with 50 percent relative cover comprises half of the total vegetation cover, whether that cover is great or small. "Ground cover" means the area of ground covered by the combined aerial parts of vegetation and of plant litter or debris produced naturally on site (30 CFR 700.1) and relates to protection from soil erosion (Hofmann et al. 1981).

Other terms used to describe cover sampling approaches are "foliar cover"--the area actually covered by the above ground parts in a directly upward or downward view; "canopy cover"--the area within an imaginary polygon around the horizontal extremities of a plant projected directly upward or downward; and "basal cover"--the outline of a plant near its base.

Methods used to measure cover include point intercepts, quadrats, and line intercepts. With point intercepts, foliar or basal cover is estimated by recording each item "hit" by the downward projection of a point held above the ground. The point usually is defined either by cross-hairs in a viewing device or by pins suspended in a frame (Figure 8). See Figure 9 for a smple point trasnect and cover calculation. With quadrats, canopy cover is estimated visually for each species within a given predefined area, which usually is on the order of one square meter or less. Cover is expressed by percent or by cover classes representing specified ranges of values. Subdivisions within the quadrat aid in making the visual estimates. With line intercepts, the portion of a tape (often 30 meters in length) intersected by aerial plant parts or imagined plant canopy polygons is recorded and tallied by species (Figure 10).

Differences in the prevalence of cover sampling techniques between the various states are not necessarily related to differences in the vegetation of the regions involved. Rather, the differing methods sometimes reflect the personal or educational background of agency staff during the period when the state programs were being developed, mostly in the late 1970s. Thus, it is not always possible to describe a "reason" for a particular method predominating in a particular state (e.g., only quadrat sampling for cover in Montana).

Cover data are not required for cropland in any of the five stated and are required for pastureland only in North Dakota. However, cover must be estimated for all native vegetation types (i.e., native rangeland and wildlife habitat) in all five states (see Table 1).

2.3.2.4 Woody Plant Density. This measurement addresses the number of shrubs or trees per unit area. Woody plant density may be sampled by

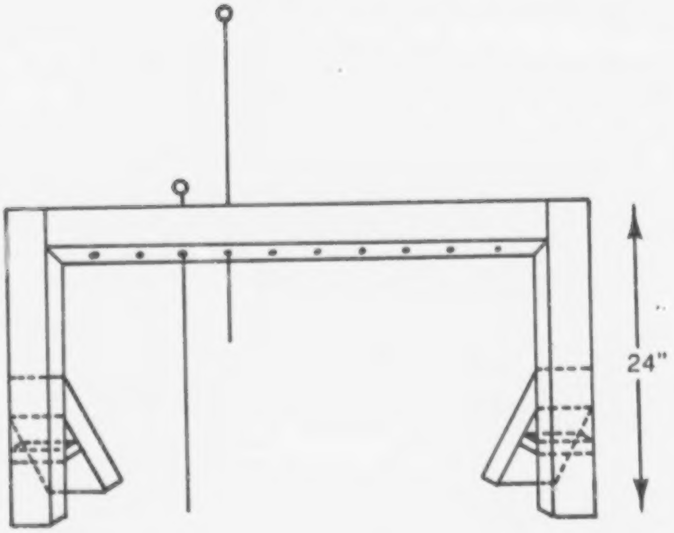


Figure 8. A point-frame, one method for measuring vegetation cover. Each interception or "hit" of the needle equals a sample point. Size of frame may vary. (from Chambers and Brown 1983)

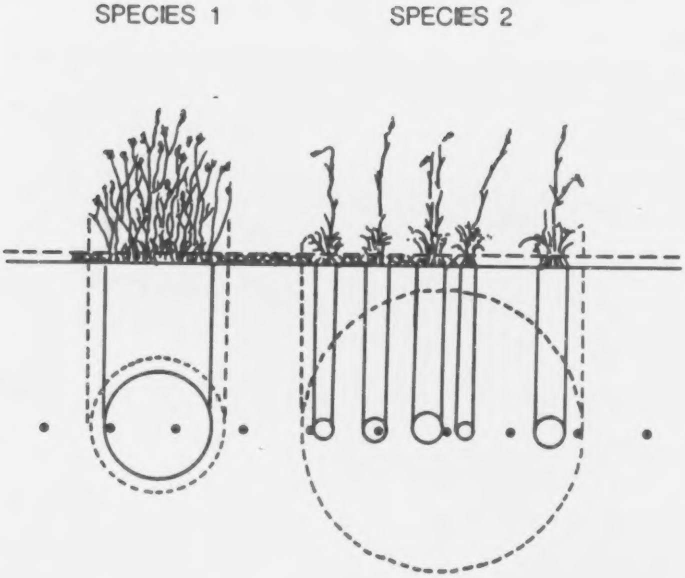


Figure 9a. Graphic representation of a point intercept transect showing ten sample points (dots), and vertical projections of foliar cover (dashed circles) and basal cover (solid circles) for two grass species. Area between plants is either bare soil (open) or litter (∞∞). (from Chambers & Brown 1983)

Figure 9b. Raw data and calculations of cover using point intercept method, based on Figure 9a.

Raw Data for Canopy Cover

First Hit (starting at left)	1	2	3	4	5	6	7	8	9	10
Species 1		X	X							
Species 2					X	X	X	X	X	
Litter				X						
Bare Soil	X									X

Raw Data for Basal Cover

First Hit (starting at left)	1	2	3	4	5	6	7	8	9	10
Species 1		X	X							
Species 2						X				
Litter				X	X		X			
Bare Soil	X							X	X	X

Calculations of Canopy Cover and Basal Cover

Canopy Cover

	Absolute Cover	Relative Cover
Species 1	2/10 = 20%	2/7 = 29%
Species 2	5/10 = 50%	5/7 = 71%
Litter	1/10 = 10%	not applicable
Bare Soil	2/10 = 20%	not applicable
Ground Cover	20% + 50% + 10% = 80%	not applicable

Basal Cover

	Absolute Cover	Relative Cover
Species 1	2/10 = 20%	2/3 = 67%
Species 2	1/10 = 10%	1/3 = 33%
Litter	3/10 = 30%	not applicable
Bare Soil	4/10 = 40%	not applicable
Ground Cover	20% + 10% + 30% = 60%	not applicable

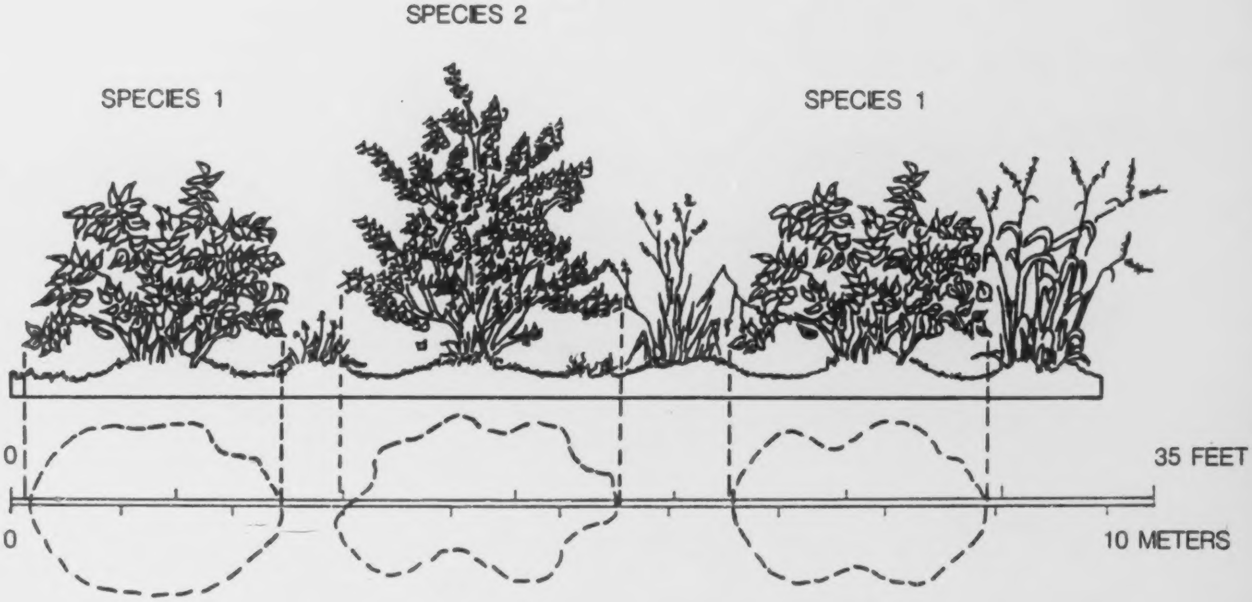

SPECIES 2
SPECIES 1
SPECIES 1
0
35 FEET
0
10 METERS

Figure 10a. Graphic representation of a line intersept transect for shrub cover showing vertical projection of canopy cover for two species as intersected by a tape. (after Chambers and Brown 1983)

Figure 10b. Calculation of shrub cover using line intercept method, based on Figure 10a.

	Species 1	Species 2
Length Intercepted	7 ft + 8 ft	8 ft
Canopy Cover	15 ft ÷ 35 ft = 43%	8 ft ÷ 35 ft = 23%

counting all individuals of each species within large quadrats or narrow belts, or by "plotless" methods such as measuring the distance from random or systematically located points to the nearest shrub or tree.

Subshrubs, which are of small stature or if tall are woody only at their bases, may or may not be counted depending upon the formal or informal guidelines of the various states. Only Wyoming consistently expects subshrubs to be included in density data for native rangelands. The paucity of upland shrubs in North Dakota is reflected by the lack of shrub density requirements on native rangelands in that state. Naturally, woody plant data are not pertinent in pastureland or cropland, but they are required for lands used as wildlife habitat.

2.3.2.5 Lifeform and Species Diversity. Within the scientific community, diversity has evolved into a concept that encompasses two separate elements: "richness"-- the number of species within a given area or vegetation type, and "evenness"--the relative proportions of the various species within the area or type (see Chambers and Brown 1983 for a more detailed discussion of diversity). Thus, for example, an area could contain numerous species but have a low diversity (or "heterogeneity") if one or two of the species comprised the vast majority of cover or biomass present. The concept of diversity may be applied to lifeforms as well as to species. Both the method of calculating diversity and its conceptual basis are important issues in revegetation of western surface coal mines (e.g., see Sections 4.4.3, 5.3, and 5.4).

All five states require collection of cover and production baseline data, which can be used to calculate species and lifeform diversity, for native rangeland and wildlife habitat. North Dakota also requires species or lifeform diversity data for pastureland. Elsewhere, pastureland and cropland land uses are exempt from diversity requirements. Examples of diversity calculations are presented later in this report (Section 4.3.2).

While lifeform and species diversity both focus within a plant community, a related concept--landscape diversity--focuses on differences between plant communities. No uniform state-to-state requirements pertaining to landscape diversity currently exist in the study area, although non-statistical requirements for specific mines have been established on a case by case basis (see case studies MT-1, MT-2, ND-1, and ND-2).

2.4 EXISTING SOURCES OF BASELINE DATA

Vegetation data have been collected in the study area for more than 50 years by the SCS and Federal agencies responsible for managing grazing lands, most notably the USFS and BLM. Data collected by these agencies have been used primarily to establish livestock carrying capacities for grazing allotments on public lands. Data also have been collected by universities and government agencies in conjunction with various research projects. In recent years, site-specific baseline data have been collected by mining companies or their consultants as part of the permit application process for coal, synfuels, uranium, or other major resource development projects.

2.4.1 Range Data

Data collected by the SCS over the years have primarily been the type used in developing and refining range site descriptions. These range site descriptions are based on the species composition and production of vegetation that could develop for a given soil type and climatic regime, free of disturbances such as fires and heavy grazing pressure. Thus, range sites are based on the potential natural or "climax" vegetation of an area, rather than existing conditions. In fact, some field characterization of range sites in "good," "fair," and "poor" condition has occurred so that carrying capacity recommendations can be modified in "technicians guides." However, the emphasis of data collection has been on areas of highest condition that are used to define the nature of the range site.

Range site data collected by the SCS usually are production estimates visually collected in ten 9.6 ft^2 plots, with at least two of the ten plots clipped to determine correction factors for the visual estimates. Sampled areas usually are protected from livestock grazing by fencing or other means. Cover data are collected only occasionally during the SCS sampling programs.

SCS range site data generally are gathered by permanent staff, sometimes assisted by seasonal employees. Most of the data in this particular form have been collected since the mid-1960s. Areas sampled in a given year often are those in which SCS soil surveys are ongoing and are sampled for about five consecutive years. Range sites that have not been sampled for some time are subject to having a new round of sampling initiated in order to update production figures. These "year-site" data usually are available from local and state offices of the SCS.

The SCS data normally are entered on what is known as SCS Range Form 417. All such data for the entire country are being entered into a large computer data bank in Fort Worth, Texas; this is referred to as the National

Range Database. Besides the SCS, principal users of SCS range data are range science faculty and students of regional universities.

The BLM also collects range data, but for vegetation more representative of actual conditions rather than from "climax" conditions such as sought by the SCS. The objective of the BLM data collection program is to determine carrying capacity on public grazing allotments. BLM data available are primarily those collected under the Soils-Vegetation Inventory Method (SVIM) program, now known as the Ecological Site Inventory Program. This resource inventory program began in 1976 and has now covered most BLM land in the five-state study region.

BLM sampling under the SVIM program was based on range sites, and the SCS was contracted to conduct soil surveys of the BLM lands sampled. As mentioned earlier, BLM range sites are defined and used somewhat differently from SCS range sites. The BLM's sampling method consists of noting the plant species present at 200 points along a paced transect. These "frequency" data are used as an index of cover and species composition. At ten of the 200 points, production is visually estimated within plots ranging in size from 0.01 to 0.1 acre. Two of the ten plots are clipped to provide correction factors for the visual estimates. The production plots apparently are almost never protected from grazing, and the data therefore are representative of some fraction of the actual total production. Personnel conducting the BLM sampling have included contractors as well as BLM permanent staff and seasonal employees.

The BLM range data are housed in hardcopy form at District Offices. An attempt to bring these data together into a computer database has begun, but its completion is not imminent. Including BLM data in the National Range

Database sometime in the future is under consideration. At present, the BLM range data can normally be accessed only by BLM personnel, although they technically are available to others.

Range data collected by the USFS generally have been based on similar methods and used for similar purposes (i.e., management of grazinglands) as the BLM data described above. However, USFS lands seldom include surface coal development areas and thus are of less relevance to this study.

2.4.2 Research Data

Research data have been collected intermittently in the study region by university and government personnel, usually for the purpose of describing and classifying vegetation or range resources in an area. This information sometimes is available in scientific journals or experiment station publications although much of it exists in unpublished form, often as university dissertations. Compared to other existing baseline data in the study region, research data are few and unevenly distributed.

2.4.3 Mine Permit Application Data

The following subsections present an overview of baseline vegetation data collected by coal mining companies as part of the permit application process. This discussion has been organized by state to facilitate a comparison of the trends that have developed under different sets of regulations and guidelines. Statements are based on permit applications on file with OSM and may not reflect modifications or additions handled through subsequent correspondence. The use of a particular method does not necessarily indicate its current acceptability to the State agency because requirements and recommendations have changed through time. See Section 2.3 above for a review of current baseline data requirements and Table 2 for a summary of the types of data contained in mine permit applications by state.

No state has thus far compiled permit application data into an easily accessed form. The permit documents are available in hardcopy form at the OSM Technical Center in Denver, the OSM field offices in Casper and Albuquerque, the respective State regulatory agency offices, and the mine company offices. The Montana DSL has indicated a desire to accomplish this task but has not yet formally begun. The Wyoming DEQ also has no formal compilation in progress, although its desirability has been discussed and an informal handwritten compilation has been undertaken by a DEQ staff member on his own initiative.

2.4.3.1 Colorado. A total of 23 mine permit documents were reviewed for Colorado. Study periods usually ranged from 1979 through 1983, with one having begun in 1974. Consultants conducted the baseline vegetation work for 19 of the mines, one mine used its own personnel, and one presented only SCS data. The SCS data were used for a mine where no premining vegetation remained.

2.4.3.2 Montana. Seven surface coal mine applications were reviewed for Montana. Most of the baseline studies were conducted between 1977 and 1981, although studies at one mine began in 1974. Four of the studies were performed by consultants, two by the mining companies themselves, and one by a combination. Duplicate cover sampling, using both quadrats and point frames, was included in one permit application apparently at the request of

TABLE 2

SELECTED VEGETATION DATA INCLUDED IN PERMIT APPLICATIONS ON FILE AT OSM*

	CO	MT	NM	ND	WY	Total
Number Reviewed	21	7	10	7	36	81
Study Dates[a]	mostly 79-83	mostly 77-81	mostly 80-83	mostly 79-83	78-82	
Work Performed by						
Consultants	19	4	4	2	29	
Company Personnel	1	2	3	1	6	
Combination	-	1	2	2	-	
SCS Data Only	1	-	-	-	1	
Unspecified	-	-	1	2	-	
Vegetation Map Units						
Range Sites	2	7	1	7	7	
Vegetation Types	19	7	9	1[b]	29	
Cover Sampling						
Quadrat (ocular est.)	5	7	3	1[b]	17	
Point Intercept	13	1	2	6	18	
Line Intercept	5[c]	4[c]	1[c]	-	7[c]	
None (SCS Data used)	1	-	-	-	1	
Cover Data						
Absolute Cover	20	7	10	7	35	
Relative Cover	5	-	2	3	13	
Species	20	7	10	7	34	
Lifeform Only	-	-	-	-	1	
Frequency Data Reported	9	7	8	7	18	
Production Sampling						
Clipping	20	7	9	6	35	
Double Sampling	-	-	-	2	3[c]	
SCS Data	1	-	-	-	1	
None	-	-	1	1[b]	-	
Woody Plant Data[d]						
Density	17	6	10	1[b]	28	
Shrub Heights	5	1	-	-	24	
Species Diversity[d]						
Richness	2	-	-	1	7	
Numerical Index	13	1	1	-	10	
Both	-	-	-	-	5	

*For native rangeland and wildlife habitat land uses only.
Data shown do not necessarily reflect correspondence between the coal company and the regulatory authority that followed submission of the application, particularly whether the authority required changes or additions and whether the proposed performance standard was accepted.

TABLE 2 (cont.)

	CO	MT	NM	ND	WY	Total
Success Standard						
Reference Area	15	5	5	4	5	
Control Area	2	-	-	-	24	
Unspecified Comparison	-	1	-	-	2	
Unadjusted Baseline	1	-	-	-	-	
Historic Record	-	-	3	-	-	
Technical Standard	-	-	-	3	-	
Ambiguous or Unspecified	3	1	2	-	5	

Key to Superscripts:

[a] Usually one year of data, except for NM.

[b] For woody draws, which are addressed in only one permit application.

[c] For shrubs only.

[d] In a number of cases, not shown here, data were submitted subsequently and are present in correspondence files.

MDSL. Montana was the only state in which all the permit applications utilized ocular estimation within quadrats for cover sampling.

2.4.3.3 New Mexico. Ten surface coal mine permit applications were reviewed for New Mexico, including two separate documents for each of two mines owned by the same company. Duplicate studies at these mines were required to correct deficiencies in the baseline data. Studies were done in 1980 or later, except for one mine in 1978 and 1979. Baseline data were collected by consultants in four cases, mine personnel in three cases, both consultants and mine personnel in two cases, and unidentified personnel in the remaining case.

2.4.3.4 North Dakota. Seven mine permit applications were reviewed for North Dakota, including two separate documents for one of the six mines because it had been repermitted. The baseline vegetation data were collected by consultants in two cases, the mining company in one case, the mining company plus consultants in two cases, and unspecified persons in two cases. Baseline vegetation studies in North Dakota were conducted between 1979 and 1983.

2.4.3.5 Wyoming. The largest number of surface coal mines in the five-state region is in Wyoming, for which 36 mine permit applications were reviewed. Vegetation baseline studies were conducted as far back as 1974, although mostly between 1978 and 1982. Twenty-nine of the studies were by consultants, six by mining company personnel, and one was merely a presentation of SCS data. In general, the mining companies placed greater reliance on range sites than did the consultants. At the one mine that presented only SCS data, the premine vegetation had been removed and only SCS data were available to define the preexisting vegetation.

Revegetation standards formally set so far consist of reference areas at one mine and technical standards at several, for example for woody plant density in the woody draw situation at case study mine ND-1. A "Wetlands Advisory Committee" composed of members representing the fields of groundwater, aquatic botany, and fish and wildlife management also has been established to oversee reclamation efforts of affected wetlands, such as at case study mine ND-2. At one mine, a technical standad was accepted for postmine land uses of hayland/pastureland for property that was premine native rangeland. Revegetation standards have not been established for the remaining North Dakota mines, although many mines have proposed reference areas. The reason that other revegetation standard systems have not been accepted is that the NDPSC is evaluating all revegetation standards, particularly in light of investigations that the PSC administered with OSM funds (Van Dyne 1984, Van Dyne and Hollingsworth 1984, Van Dyne and Van Dyne 1984, Van Dyne and Wali 1984).

2.5 REVEGETATION MONITORING REQUIREMENTS

All states in the study area except Colorado currently require monitoring of revegetation, although none requires that detailed monitoring data be submitted prior to the evaluation of revegetation success, unless specified as a permit stipulation. Montana requires the submittal of data summaries as part of the mine's annual reports. These usually consist of the averaged cover and production data for all reclaimed sites in a given permit area.

While Colorado is the only state currently with no requirement for monitoring reports, MLRD revisions presently under review would require periodic submittal of quantitative data. If approved, this revision will make Colorado the only state specifying that the monitoring reports include quantitative data.

The net effect of the current requirements is that monitoring data, when they exist, are not readily accessible beyond the individual mines. In some cases they may not be analyzed promptly because submittal is not mandatory. However, a few mines have submitted monitoring data to the regulatory authority even without a strict requirement to do so.

2.6 REVEGETATION DATA AND PLANNING

2.6.1 Existing Sources of Revegetation Data

The two main sources of revegetation data in the study area are monitoring studies at the mines and ongoing research programs by public or private institutions or the mines themselves. The main purpose of monitoring studies is to check the progress of revegetation in the years prior to testing for final bond release.

Methods of gathering revegetation data vary. Revegetation research generally uses standard biological field, experimental, and analytical techniques. Monitoring programs tend either to be qualitative or to use some of the same quantitative techniques as the baseline data collection but applied less intensively. Usually, only the most easily measured vegetation parameters are sampled during monitoring, i.e., cover or shrub density. Monitoring data are collected by coal company reclamation personnel or consultants.

The accessibility of revegetation data varies. Relatively rapid information exchange among coal companies and some researchers occurs at workshops and conferences (such as the biannual conference at Billings, Montana) and through informal contacts. Publication of research in journals or public documents may involve a considerable time lag, but the published information is more readily accessible by a larger audience. Monitoring data are not a readily available source of revegetation information because they are kept in-house at coal companies or sequestered in annual reports on the shelves of State or Federal regulatory agencies.

A program of revegetation monitoring at four coal mines in Montana was carried out by the Montana DSL from 1976 through 1984. The DSL data were collected by the methods recommended in the Montana Draft Vegetation Guidelines for cover, production, species diversity, and species composition. Most of the data were for recently reclaimed areas, with 1-4 years of collection at each site. This is the only case in the study area where a regulatory authority has conducted such an extensive program, and also the only one in which agency studies have duplicated industry studies. The DSL monitoring program is being evaluated to determine how it should be continued.

An inventive program of experimentation is in progress at an older mine in North Dakota (Case Study ND-1), where pre-SMCRA sites are being used as experimental plots for testing newer revegetation techniques. Successful procedures will be used on post-SMCRA sites if permitted by the regulatory authority.

2.6.2 Reclamation Seed Mixes

The decisions involved in formulating postmine seed mixes exemplify how revegetation data are actually utilized in the permitting process. Given postmining land uses of native rangeland or wildlife habitat, the actual determination of the composition of reclamation seed mixes is typically based upon (1) the knowledge of the coal company revegetation specialist and the state regulatory authority revegetation personnel concerning species performance and availability, (2) the overall revegetation strategies used at the mine, and (3) the specific approaches preferred by the coal company revegetation specialist and regulatory authority personnel.

In terms of formal procedures, the coal company submits its proposed reclamation seed mix to the regulatory authority as part of its permit application. The mix is either accepted or revised at the request of the regulatory authority. The company can change its seed mix at a future time by requesting and receiving approval for the change from the regulatory authority.

Good candidates for the seed mix would be desirable, available species that are present in the premining vegetation, are appropriate for the postmining land use, and can be readily re-established. Knowledge of species performance is typically acquired from mines in the same region having similar reclamation sites and from Federal or State research agency information. Availability of native species, more uncertain than the supply of introduced species, is typically via either on-site collection or commercial seed sources. A major reason for the uncertain availability of native species is that many produce seed crops that vary widely from year to year.

Therefore, those natives that are more consistently available will tend to be chosen over those with uncertain availability.

The overall revegetation strategy relates to the landscape diversity at the mine, and whether one seed mix with diverse species is used at all reclamation sites or a number of more specialized seed mixes are used for ecologically distinct reclamation sites (e.g., lowland versus upland). Case study mines NM-1 and CO-2 exemplify the single mix approach, while MT-1 and WY-1 are examples of the multiple mix approach.

The revegetation approaches preferred by mining company and agency personnel reflect real differences in philosophy about the best way to achieve successful revegetation. For example, methods to achieve improved lifeform and species diversity can include changes in seed mix species composition, seeding rates, or cultural and management practices (see other parts of this section). There currently is no set procedure for achieving this goal and reclamation specialists are experimenting with a variety of techniques.

2.7 REVEGETATION PERFORMANCE STANDARDS

The legal bases for revegetation performance standards have been discussed in Section 2.3. No post-SMCRA reclaimed lands have reached the end of the 10-year liability period when revegetation success can be evaluated, and therefore no revegetation performance standards have yet been applied.

Table 3 shows Federal and current State performance standards by land use category for three different aspects of revegetation: (1) vegetation parameters, such as cover, production, woody plant density, and lifeform and

TABLE 3

REVEGETATION PERFORMANCE STANDARDS BY LAND USE CATEGORY

Postmining Land Use	Federal 1979 Permanent Regulatory Program (PRP)	Federal 1984 Permanent Regulatory Program (PRP)
All Land Uses	Diverse, effective, and permanent cover of the same seasonal variety able to support postmining land use.	Diverse, effective, and permanent cover of the same seasonal variety able to support postmining land use.
Native Rangeland	For states with average annual precipitation under 26 inches, in the last two consecutive years of the responsibility period: Ground cover 90% of standard with 90% confidence or 80% confidence on shrublands; Productivity 90% of standard with 90% confidence or 80% confidence on shrublands.	For states with average annual precipitation under 26 inches, in the last two consecutive years of the responsibility period: Ground cover 90% of standard Production 90% of standard
Wildlife Habitat	Ground cover 70% of standard with 90% confidence or able to control erosion. Woody plant stocking 90% of standard with 80% confidence.	Ground cover shall not be less than that required to achieve the approved postmining land use. Woody plant stocking to be specified by regulatory authority.
Cropland	Production 90% of standard with 90% confidence.	Production 90% of standard.
Pastureland	Same as Cropland.	Same as Native Rangeland.
Grazingland: Native Rangeland and Pastureland	Use by livestock at a grazing capacity approved by the regulatory authority approximately equal to that for similar non-mined lands.	None
Revegetation Standard System	Reference area or other approved standard.	Reference area or other approved standard.

TABLE 3 (cont.)

Postmining Land Use	Colorado (CO)	Montana (MT)
All Land Uses	Same as 1979 and 1984 PRP.	Same as 1979 and 1984 PRP.
Native Rangeland	Cover and production same as 1979 PRP. Woody plant density same as 1979 PRP wildlife habitat.	Cover and production with same statistical measures as 1979 PRP, but comparison is to weighted cover and production (see text). Woody plant density same as 1979 PRP wildlife habitat. Weighted diversity (see text) with same statistics as cover in 1979 PRP. Permanence: if 51% of cover and production are by native species.
Wildlife Habitat	Same as Colorado Native Rangeland.	Same as Montana Native Rangeland.
Cropland	Same as 1979 PRP.	Same as 1979 PRP but for last 5 years.
Pastureland	Same as 1979 PRP Cropland.	Same as 1979 PRP Cropland.
Grazingland: Native Rangeland and Pastureland	Same as 1979 PRP.	Same as 1979 PRP.
Revegetation Standard System	Reference area or technical standard.	Reference area or technical standard.

TABLE 3 (cont.)

Postmining Land Use	New Mexico (NM)	North Dakota (ND)	Wyoming (WY)
All Land Uses	Same as 1979 and 1984 PRP.	Same as 1979 and 1984 PRP.	Same as 1979 and 1984 PRP.
Native Rangeland	Cover and production same as 1979 PRP. Woody plant density same as 1979 PRP Wildlife Habitat.	Cover and production same as 1979 PRP.	Cover and production same as 1979 PRP.
Wildlife Habitat	Same as 1979 PRP.	Same as 1979 PRP but only for last year.	Same as Wyoming Native Rangeland. Shrub density same as woody plant "stocking" in 1979 PRP.
Cropland	Same as 1979 PRP.	Same as 1979 PRP.	Same as 1979 PRP.
Pastureland	Not applicable.	Same as North Dakota and 1979 PRP Native Rangeland.	Same as 1979 PRP Cropland.
Grazingland: Native Rangeland and Pastureland	Same as 1979 PRP.	Same as 1984 PRP (none).	Same as 1979 PRP.
Revegetation Standard System	Reference area, technical standard, or historical record.	Reference area or other standards. Technical standards have been accepted.	Reference area or control area. Technical standards under review.

species diversity; (2) statistical comparability standards, such as considering cover equal if it is at least 90 percent of the standard with 90 percent statistical confidence; and (3) revegetation standards systems, such as reference areas or control areas, which are used to establish the specific numerical goals and to adjust them for climatic fluctuations (see Section 4.4).

Table 3 reveals that most of the variability among the regulatory programs is related to postmining land use. Also, although all programs accept reference areas, the states differ on the acceptance of other systems for adjusting the performance standards. Croplands and pasturelands have similar state performance standards throughout the study area, except that North Dakota requires cover and lifeform or species diversity data as well as production data for pasturelands.

Native rangeland performance standards are similar throughout the study area. The Colorado, Montana, and New Mexico programs explicitly address woody plant density as well as cover and production. Wyoming effectively requires a woody plant density performance standard on native rangelands but only as a coincidence of the fact that they are concurrent with wildlife habitat in all cases. The only state program in the study area where woody plant density data are not required for native rangelands is in North Dakota, where the dominant vegetation supporting this land use is upland grassland lacking substantial shrub cover.

Wildlife habitat performance standards are more variable among the states. The New Mexico and North Dakota programs follow the Federal regulations in treating wildlife habitat as distinct from native rangelands and requiring only woody plant density and ground cover. The Colorado and

Montana programs treat wildlife habitat and native rangeland as concurrent land uses and thus require similar performance standards (cover, production, and woody plant density). The Wyoming program treats wildlife habitat as distinct from native rangeland but, as noted above, all native rangelands also are designated as wildlife habitat, so the standards are de facto identical.

Grazinglands include both native rangeland and tame pastureland. Performance standards for test grazing in Colorado, Montana, New Mexico, and Wyoming are the same as those of the 1979 Federal regulation. North Dakota has no formal requirements for test grazing. Section 4.5 discusses grazing further.

Montana DSL's performance standards have two anomalous features: (1) including a formal definition of permanence (see Table 3), and (2) using weighted values of cover, production, and lifeform or species diversity as performance standards. Regarding permanence, MDSL is the only agency to specifically address this performance standard, which is considered to be achieved if the revegetated area is composed of at least 51 percent native species, based upon production and cover. The concept is that native species are more permanent because they are adapted to long-term ecologic patterns in the region. Weighted canopy cover (or weighted production or lifeform and species diversity) is calculated for each of several morphological or lifeform classes, which are defined as shrubs, annual grasses, perennial grasses, and annual, biennial, and perennial forbs. In the calculation for each morphological class, the amount of postmine cover in each vegetation type is weighted by the relative areal extent of that type in the permit area. Weighted canopy cover for each lifeform in the reference area is compared to that of the affected area. Decreases in a morphological class are allowed if it is composed of undesirable species for both wildlife and livestock and is offset by a higher weighted canopy cover in another morphological class. The calculation of weighted diversity includes only species with greater than 1 percent cover. A potential problem with the use of weighted measures is that a particular postmine vegetation type could have a definitely different lifeform composition than the corresponding reference area if another postmine vegetation type had a compensating change in the same lifeform class.

- All the performance standards have been potentially affected in some way by the 1984 revisions to the Federal regulations (Table 3). Any standards that were made less strict by the revisions would still be satisfactorily addressed by the existing State programs, which were all approved on the basis of the 1979 regulations. Any standards that were made more strict by the revisions would theoretically require appropriate changes in the State programs.

The performance standards for wildlife habitat are the only ones made less stringent in the 1984 Federal regulations. The lessened stringency stems from the deletion of specifications for statistical comparability of ground cover and woody plant density. Standards for tame pastureland were made stricter in the 1984 Federal regulations. Tame pastureland must now meet both productivity and cover standards, whereas only productivity standards were required for this land use by the earlier regulations.

Cropland and native rangeland performance standards appear similar in both sets of Federal regulations, but they actually are stricter in the later set. The 1984 regulations state that "ground cover, production, or stocking [woody plant density] shall be considered equal to the approved standard when they are not less than 90 percent of the success standard" [30 CFR 816.116(a)(2)]. The 1979 Federal regulations provided more flexibility by allowing a 90 percent confidence level (or 80 percent confidence in the case of shrublands) around the 90 percent standard. That is, the 1984 Federal regulations specify only that 90 percent of the success standard must be attained, with no additional percentiles of difference to allow for the natural variability in cover or production (i.e., apparently a 100 percent confidence level). Especially for shrublands used as native rangeland, the apparent change from an 80 percent confidence level in 1979 to a 100 percent confidence level in 1984 is likely to cause undesirable (and unrealistic) inflexibility in the success standards.

A related but less significant change is that the 1984 Federal regulations specify sample adequacy in part, whereas the 1979 regulations did not. The former [30 CFR 816.116(a)(2)] specifically state that "The sampling techniques for measuring success shall use a 90-percent statistical confidence interval (i.e., one-sided t-test with a 0.10 alpha error)." However, since there is no mention of the amount of reduction the sampling techniques are designed to detect, some flexibility remains. A third change is that the 1979 requirement for grazing of native rangeland and tame pastureland for the last two years of the liability period is absent from the 1984 regulations. This could adversely affect the ability of regulatory authorities to evaluate the attainment of "permanence."

2.8 METHODS OF PREDICTING AND EVALUATING REVEGETATION SUCCESS

2.8.1 Predicting Revegetation Success

Revegetation technology has advanced rapidly in the past several years. However, the results obtained by using these newer techniques at western surface coal mines are only now becoming available, and they therefore are of limited utility as a basis for predicting future successes or failures.

The only serious attempt at developing a model for predicting revegetation success in the study region used data collected in 1976 and 1977 for sites revegetated under pre-SMCRA requirements as well as from unmined areas (Packer et al. 1982). This model, which addressed both production and cover, assumes three factors to be driving (independent) variables: annual precipitation, growing season length, and age of planting. The dependent variables addressed by the model are cover and production; woody plant density and lifeform or species diversity are not addressed.

The forage production and cover models for mined land are two-part expressions as follows: f_1 (annual precipitation, growing season length, age of planting) + f_2 (soil potassium, soil sodium, pH, and seven revegetation treatments--tillage, seeding method, presence or absence of topsoil, fertilizer, irrigation, mulching, and spring or fall seeding time). The adjustments for soil potassium, sodium, etc. in the second half of the expression are in the form of direct additions or subtractions of forage production or percent cover. The factors of annual precipitation, growing season length, and age of planting are used in complex, empirically derived exponential expressions.

The authors of the model acknowledge that the base data are weak in many respects and that variation in cultural treatments and the young age of most of the revegetation samples confound potential conclusions from the data. They recommend that this model be used with "considerable discretion." As with any mathematical model, the usefulness is seriously weakened when major sources of variation in the base data are not identified as separate variables. Since the technology of revegetation has developed so rapidly over the past several years, it would be hard for any model to remain "current. Nevertheless, this model has been cited in the Technical Evaluation and Analysis (TEA) documents of several Northern Great Plains mine permit applications.

The most valid technique for predicting revegetation success under SMCRA requirements at most locations is to consider results of the newest technology at other mining operations in the region which have similar soil, overburden, and local climatic characteristics. This case-by-case approach is essentially the technique used by State regulatory personnel when making their Technical Evaluation and Analysis of permit applications. It also is the basic technique available to agencies such as the BLM for impact prediction in Environmental Impact Statements.

2.8.2 Evaluating Revegetation Success

The success of revegetation on native rangeland and wildlife habitat is evaluated on the basis of cover, production, lifeform or species diversity, permanence, and woody plant density. Performance standards for lands in other uses, such as mown pastures, row crops, or commercial forests, consist of subsets of the native rangeland and wildlife habitat standards.

Provisions in Federal and State laws requiring that reclaimed areas support an equal or higher land use than before mining are reflected by regulatory requirements for re-establishing levels of cover, production, and woody plant density equal to or greater than an approved standard. The revegetation standards mentioned in the Federal regulations (30 CFR 816.116

and 30 CFR 816.117) are those set by reference areas or "technical guides" approved by the regulatory authority.

In practice, woody plant density and lifeform or species diversity have come to be addressed as technical standards for reasons discussed in Sections 4.4.2 and 4.4.3, respectively. Cover and production revegetation standards are set using one of five techniques: unadjusted baseline values, control areas, reference areas, historic records, or technical standards (described below). Unadjusted baseline values and technical standards incorporate no adjustment for year-to-year environmental (mainly meteorological) fluctuations. The other methods address year-to-year variation in one way or another. Adjustments for environmental variability avoid the potential of having standards too low because they were based on dry years, or too high because they were based on wet years.

The difference between the various approaches currently in use are summarized in Table 4 and discussed in the following subsections.

2.8.2.1 Unadjusted Baseline. This approach uses quantitative values for cover and production, recorded during the baseline study as the revegetation standard, with no adjustment for natural variability due to environmental change. The implicit assumption is that year-to-year fluctuations in the measured parameters are negligible. This approach has not been used widely except for existing small mines that lack sufficient land for reference areas.

2.8.2.2 Control Areas. With this approach, small parcels (usually 2-3 acres) selected to be representative of each vegetation type and located in

TABLE 4

SUMMARY OF SYSTEMS FOR EVALUATING REVEGETATION SUCCESS

System	Source of Data for Revegetation Standard	Typical Period of Data Collection	Typical Year-to-Year Climatic Adjustment
Unadjusted Baseline	On-site affected area baseline data	1 year	None
Technical Standards	Regional data	several years	None at present
Control Area	On-site affected area baseline data	1 year	As reflected by test year/ baseline year ratios of cover and production in control area
Reference Area	On-site reference area	1 year	As reflected in reference area
Historical Record	On-site affected area baseline data	7 years	As reflected in data collected over one "climatic cycle"

areas that will remain undisturbed by mining, are sampled for cover and production at the same time as vegetation in areas to be mined (i.e., the "affected area"). At the time of testing for revegetation success, the revegetated areas are sampled and the corresponding control areas re-sampled. Values for the control area in the test year are compared to values in the baseline year, and the ratio between the two is used to adjust the baseline values of cover and production for the affected area. The adjusted affected area baseline data, in turn, are the basis for evaluating the revegetated areas. That is, the performance standards are set by the baseline data for the affected area before mining, but adjusted for effects of meteorological fluctuations as indicated by the control area.

The use of control areas assumes that variations in vegetational characteristics within a 2-3 acre control area closely parallel the average of those in an affected area many times larger (up to thousands of acres). This technique is used at most mines in Wyoming but few mines elsewhere.

2.8.2.3 Reference Areas. This is like the control area method in that a small parcel of 2-3 acres is chosen to represent each vegetation type in the affected area. It differs, however, in that values of cover and production within the reference areas in a given year set the revegetation standard. Thus, the baseline data for the affected area vegetation types are used only to establish comparability with the corresponding reference areas; that is, the reference area data rather than the affected area baseline data are used as the basis for judging revegetation success.

As with control areas, the use of reference areas assumes parallel variability between a small 2-3 acre parcel and average values over a vastly larger affected area vegetation type. Indeed, the reference area approach is even more strongly dependent on this assumption because the reference area values are the actual standards, rather than being used to adjust standards derived from more spatially widespread affected area baseline data. Reference areas are used throughout the study area.

2.8.2.4 Historic Record. A much less widely used method for addressing the temporal variation of vegetation is to collect baseline data yearly for a period considered to be one climatic cycle, thereby theoretically bracketing the potential variability in cover and production. New Mexico MMD, the only state agency that has used this approach to a significant degree, typically considers a climatic cycle to encompass 7 years.

It is not clear exactly how the accumulated data would be used to judge revegetation success. One method set forth in a joint meeting between the MMD and OSM is to use the arithmetic mean of the historic record data as a technical standard (memo of 2/5/81). This could result in revegetation being deemed inadequate in a wet year but which would fail to meet the standard if it were evaluated in a normal or dry year. It therefore would seem necessary to examine the variability of the baseline data over the climatic cycle (baseline period) and to compare climatic conditions of the test year with those of the closest baseline year. If the test year climatic conditions are outside the range of the historic record, then further monitoring would be indicated.

Another possible method would be to sample the reclaimed area over a period comparable in length to the baseline period and to compare the means with 90% confidence intervals. However, this would necessitate a longer period of sampling than the mandated 2 years at the end of the liability period. The large amount of sampling involved in historic record construction to date could be substantially reduced if the entire program were viewed as a sample stratified by year (Buckner 1983).

2.8.2.5 Technical Standards. The Federal regulations [30 CFR 816.116(a)] allow the use of approved technical standards to establish revegetation success standards. Like unadjusted baseline data, technical standards do not specifically provide a means of adjusting success standards to compensate for environmental fluctuations. Range site descriptions normally incorporate ranges of production from most favorable to least favorable years, and so might provide a basis for evaluation of production values of revegetated areas in the context of the general "favorability" of the test year.

At present, there are no widely accepted technical guides for cover and production. Range site data available from SCS have been used in a few cases. The large body of cover and production data in mine permit applications could potentially be used to develop technical standards. Ideally, these would be developed by ecological region (e.g., SCS Land Resource Areas) and include some climatic adjustment. Technical standards currently are used primarily for woody plant density and lifeform or species diversity parameters, as discussed in 4.4.2 and 4.4.3.

2.9 REVEGETATION RESEARCH AND INNOVATION

Information on major revegetation research centers and programs for the study area is summarized in Table 5. The table includes Federal, State, and private research projects, Federal agencies that have funded revegetation

TABLE 5

SURVEY OF RESEARCH CENTER REVEGETATION PROGRAMS IN THE STUDY AREA

Agency	Program/Center	Description	Status	Sources of More Information
FEDERAL				
1.0 Department of Agriculture				
1.1 Agricultural Research Service (ARS)	Northern Great Plains Research Center, Mandan, ND (NGPRC)	This group has worked closely with the Land Reclamation Research Center of NDSU since the groups started reclamation research over 10 years ago. The groups have carried out research in Mandan and at most ND mines on substrate-vegetation relationships and species establishment and culture, both on rangelands and croplands.	NGPRC funding winding down for reclamation work, but NDSU (9.1) funding continues.	Ries 1982 Ries & Hofman 1984
	High Plains Grassland Research Center, Cheyenne, WY	Research on reclamation has included work on dryland sodding, improving shrub establishment methods, soil amendments, effects of topsoil thickness on vegetation performance, heavy metal content and nutritional quality of plants on reclaimed surfaces, soil erosion rates and control on reclaimed land, effects of grazing on revegetated areas, as well as pioneer work with stubble mulch.	Efforts redirected to soil erosion research	Howard et al. 1979 Stanley et al. 1982 Schuman et al. 1984 Hartley & Schuman 1984 Ranzi & Schuman 1982
1.2 Forest Service (FS)	Surface Environment and Mining Program (SEAM)	Started in 1973, this program funded over 150 projects that concerned all aspects of reclamation in the West. Many projects were carried out at the other Forest Service research centers listed below. Work was applicable to most of the study area.	Discontinued in 1979	U.S.F.S. 1979 Colling 1980
	Missoula Equipment Development Center, MT (MEDC)	MEDC started in the 1960's with a focus on range equipment and was very active in the 1970's on revegetation projects. Equipment was designed and adapted for all aspects of western revegetation. Another equipment development center is located in San Dimas, CA (SDEDC).	MEDC discontinued reclamation work 2 years ago	Brown & Hallman 1984 Larson 1980 Long et al. 1984

TABLE 5 (cont.)

Agency	Program/Center	Description	Status	Sources of More Information
	Vegetative Rehabilitation and Equipment Workshop (VREW)	VREW is an informal organization interested in developing and testing revegetation equipment and providing information about equipment for rangeland improvement and disturbed land reclamation. The annual meetings are attended by representatives of public agencies, universities, industries, and other organizations. Close ties with the Society for Range Management, MEDC, and SDEDC and funding by many federal and state agencies have allowed VREW to be effective. Major funds have come from USDA F.S., Extension Service-Natural Resources, SCS, and from USDI FWS, OSM, Bureau of Indian Affairs, and BLM.	Ongoing	Larson 1982 VREW Annual Reports
	Intermountain Forest and Range Experiment Station, Ogden, UT: --Mined Land Reclamation Project of the Forestry Sciences Lab, Logan, UT, in cooperation with USU	Since 1966, research on reclamation of mined lands has been carried out at various locations in the study area and beyond. During the 1970's, work focused on development of techniques for establishing appropriate vegetation communities. Starting in 1984, most work on non-severe sites was discontinued. Current foci of work are (1) sites receiving average annual precipitation of less than 12 inches or having phytotoxic conditions such as saline, alkaline, or acid-forming soils; (2) in moister sites, productivity, soil, and successional patterns; (3) the influence of mining on watershed hydrology; and (4) quality of water coming from mined lands.	Ongoing but funding cut in 1984	Chambers & Brown 1983 Ferguson & Frischknecht 1983 Packer et al. 1982
	--Shrub Sciences Lab, Provo, UT, in cooperation with BYU	This lab focuses on development of shrubby plant materials for disturbed lands of all kinds. Within the study area, their work would be most useful for CO, WY, and NM. The Shrub Sciences Lab is also the headquarters for a shrub research consortium. The topic of a recent symposium was saltbush (*Atriplex* spp.), which includes the currently most successfully seeded shrub species in the study area.	Ongoing	McArthur 1981 Tiedemann et al. 1983

TABLE 5 (cont.)

Agency	Program/Center	Description	Status	Sources of More Information
	Rocky Mountain Forest and Range Experiment Station, Ft. Collins, CO:			
	--Rapid City, SD, in cooperation with SD School of Mines and Technology	Since the early 1970's, research related to mined land reclamation has centered on the woody and aquatic communities of the Northern Great Plains, particularly in WY and ND. These are communities of great importance for wildlife habitat. A major problem to be addressed is the "lack of techniques to establish multispecies plant communities" and lack of "knowledge of natural succession trends and rates on mine spoils." Shrubs and forbs are the foci of the work.	Ongoing	Bjugstad 1984 Institute for Natural Resources, Compiler, 1983
	--Albuquerque, NM	Work has centered on plant materials and cultural treatments for disturbed, arid sites. The role of mycorrhizae in revegetation and approaches to water harvesting and irrigation have been foci of research. Long-term monitoring of Rio Puerco grazing allotments and relation to revegetation standards is ongoing.	Ongoing	Aldon, various dates, see references Aldon 1984
1.3 Soil Conservation Service (SCS)	State Offices	The SCS state and district offices have information on available plant materials and on the recommended cultural practices for regions within the states.	Ongoing	
	Plant Materials Centers, Meeker, CO; Bridger, MT; Los Lunas, NM; Bismarck, ND	The Centers collect, test, develop, and distribute varieties of plants that have potential use for reclamation of disturbed lands among other uses. Work on reclamation started in the early 1970's and was funded by various agencies such as the FS, SEAM, EPA, and OSM.	Winding down reclamation work	Thornburg 1982
2.0 Department of the Interior				
2.1 Geological Survey (GS)	Geochemical Survey of the Western Energy programs	Extensive characterization of geochemical baseline of western plants and soils.	Ongoing	Gouch & Severson 1982

TABLE 5 (cont.)

Agency	Program/Center	Description	Status	Sources of More Information
2.2 Bureau of Land Management (BLM)	Energy Minerals Rehabilitation Inventory and Analysis (EMRIA)	EMRIA program carried out surveys of various ecological components (hydrology, soils, vegetation, wildlife) in coal regions of western U.S.	Discontinued	BLM 1975
2.3 Bureau of Mines (BM)	Spokane, WA, and Denver, CO	The BM funded a variety of reclamation research in the 1970's with a focus on techniques. Examples of research concerning vegetation included work on irrigation systems, a modified front end loader bucket for transplanting native vegetation, and dryland sodding.	Revegetation research discontinued	Bunin et al. 1982 Sherman & Sullivan 1980
2.4 Fish and Wildlife Service (FWS)	Plant Information Network, Ft. Collins, CO (PIN)	PIN was a computerized information storage and retrieval system designed to provide information about plant species and vegetation for land and resource management. The data bank covers the study area with the exclusion of NM and includes about 5,000 native or naturalized vascular plant species.	Computer database discontinued; information on hard copy as FWS publication	Dittberner & Olson 1983
	Western Energy Land Use Team, Ft. Collins, CO (WELUT)	Since the 1970's, WELUT has carried out and sponsored work on revegetation of mined lands with particular emphasis on wildlife habitat.	Redirected to wetland classification research	Proctor et al. 1983a,b
2.5 Office of Surface Mining (OSM)	Washington, D.C. and Denver, CO	OSM has sponsored work by some of the other programs listed in this table. Another noteworthy study carried out by CSU and then by UND-Project Reclamation was an evaluation of available vegetation data and sampling procedures for the development of vegetation assessments in ND.	Revegetation research funding discontinued	VanDyne & Hollingsworth 1984 VanDyne & Wali 1984
3.0 Department of Energy (DOE)	Washington, D.C.	The DOE funded reclamation work in the study area in the last decade.	Discontinued	White et al. 1982
4.0 Environmental Protection Agency (EPA)	Interagency Energy/Environment Research and Development Program	This program funded vegetation related work during the 1970's. Examples include support for SCS Plant Materials Centers, for FS revegetation work, and for the FWS PIN system.	Reclamation support discontinued	

TABLE 5 (cont.)

Agency	Program/Center	Description	Status	Sources of More Information
5.0 National Science Foundation (NSF)	Washington, D.C.	One of the few ongoing substantial research programs at western coal mines is at Kemmerer Mine, WY, where the Institute for Land Rehabilitation of USU has a multidisciplinary study.	Ongoing	Institute for Land Rehabilitation 1984
STATE				
6.0 Arizona				
University of Arizona, Tucson (UA)	Mine Reclamation Center, AR Mining and Mineral Institute	Was contracted to the FS and EPA to compile reclamation references and prepare periodic publications of such references under the title "SEAMALERT."	Discontinued about 1980	
7.0 Colorado				
7.1 Colorado State University (CSU)		Faculty have worked on various aspects of revegetation of western surface disturbances including fertilizer requirements, topsoil depth effects, plant materials, development of dryland sodding, woody plant establishment techniques, mycorrhizal patterns in revegetation, and detailed study of succession on revegetated areas.	Funding changes have redirected efforts to basic ecological research	Cook & Bonham 1977 McGinnies & Nicholas 1980 Nicholas & McGinnies 1982 Redente & Cook 1984 Reeves et al. 1984
7.2 Colorado School of Mines Research Institute (CSMRI)		Work on reclamation of surface mined lands in the Northern Great Plains, including soil depth studies and uptake of heavy metals in reclaimed area plants.	Reclamation work discontinued.	Barth & Martin 1982

TABLE 5 (cont.)

Agency	Program/Center	Description	Status	Sources of More Information
8.0 Montana				
8.1 Montana State University, Bozeman (MSU)	Reclamation Research Unit (RRU)	Since the early 1970's, the RRU has carried out research at most of Montana's coal mines covering various aspects of reclamation and has produced over 100 reports. Coal companies provided support. Much of the experimentation at MT mines (see Table 6) follows from RRU work.	Revegetation work greatly reduced	DePuit et al. 1982 DePuit et al. 1980 Munshower & Fisher 1984
	Institute for Natural Resources (INR)	Since the mid-1970's, the Institute has developed and distributed computerized programs for reclamation planning. It does not specialize in vegetation data.	Ongoing	Burroughs et al. 1982
8.2 University of Montana, Missoula (UM)	School of Forestry	Faculty carried out work on ponderosa pine ecology and re-establishment at MT surface coal mines. Coal companies have funded the work.	Winding down	Stark 1982
9.0 North Dakota				
9.1 North Dakota State University (NDSU)	Land Reclamation Research Center (LRRC)	LRRC works closely with the ARS group in Mandan within the NGPRC. Primary funding of LRRC comes from ND Coal Severance Tax monies.	Ongoing	Doll et al. 1984a,b
9.2 University of North Dakota, Fargo (UND)	Project Reclamation	This research was ecosystem oriented as opposed to the agricultural orientation of the work of NGPRC and NDSU in Mandan, ND. Work at a number of mines began in the 1970's and involved both aquatic and terrestrial ecosystems. Funding was provided by BM, EPA, OSM, FS, and ND PSC.	Discontinued	VanDyne & Wali 1984

TABLE 5 (cont.)

Agency	Program/Center	Description	Status	Sources of More Information
10.0 Utah				
10.1 Brigham Young University, Provo (BYU)	Department of Botany and Range Science	Work focuses on development of shrubs capable of long-term success on arid sites at the Navajo Mine, NM. Saltbush (Atriplex spp.) hybrids are promising because saltbushes do relatively well on arid, severe sites and saltbush hybrids with lots of potential variability can be bred. This variability confers adaptability to sites that change rapidly, as do reclaimed lands. The approach contrasts to that of the SCS, which generally produces strains with little variability.	Ongoing	Stutz 1983 Stutz 1982
10.2 Utah State University, Logan (USU)	Institute for Land Rehabilitation (ILR)	Prior to 1982, ILR focused on improving plant materials and methods for arid mined lands. Since 1982, the ILR has been reorganized into an umbrella organization for about 40 associates located in 16 departments at USU. Vegetation is only one of many disciplines now represented in ILR projects. The primary ILR reclamation projects is an NSF-funded multidisciplinary study at a mine in southwest WY. This project aims to apply certain aspects of ecological theory so that rates of succession will be accelerated on mined lands. For example, the role of soil microbiota in accelerating succession is being studied.	Ongoing	Institute for Land Rehabilitation 1984 Allen 1984 Williams & Allen 1984
11.0 Wyoming				
University of Wyoming (UW)	Department of Range Management	Emphasis on the technology of cool season grass establishment, the effects of different topsoiling strategies, and the use of amendments in revegetation of bentonite spoil.	Ongoing, but reduced funding	DePuit 1982, 1984 Smith et al. 1983,1984
PRIVATE				
12.0 Argonne National Lab, Argonne, IL	Land Reclamation Program	Undertook long-term studies of the effect on direct haul versus stockpiled topsoil on revegetation characteristics at a mine in southwest WY. Also started long-term studies of soil microbiota and nutrient pools in the revegetated sites.	DOE funding removed in 1981; program discontinued across country	Jastrow et al. (in press) Miller (in press)
13.0 Native Plants, Inc., Salt Lake City, UT (NPI)		NPI has worked on development of technology for use of containerized plants in revegetation, assessment of revegetation problems in areas with acid spoil, assessment of characteristics of coal waste in CO and UT, use of tissue culture in plant material propagation, and development of technology for innoculation of mycorrhizae into reclaimed area plants.	Ongoing	Hansen 1983 White et al. 1982 Biermann & Linderman 19

research, and examples of revegetation experimentation conducted by coal mine personnel. The latter usually consist of trials of new procedures or materials to answer specific questions at their mines. For example, case study mine ND-1 in North Dakota has studied woody draws in order to improve their reclamation planning, and case study mine WY-1 in the Powder River Basin of Wyoming has conducted several carefully designed statistical investigations of cultural techniques. Usually coal companies wanting a formal research program have contacted regional universities or government research agencies. Coal companies also may provide financial support to research groups, such as the Montana State University Reclamation Research Unit (RRU) which has used industry funds to study the effects of fertilizers, irrigation, and mulch.

Two main points emerge from Table 5. First, the major agency involved with revegetation research has been the USFS. Second, there has been a marked decrease in research activities in the last five years in contrast to the abundant research in the mid 1970s. Government agencies such as DOE that formerly funded many revegetation research projects have greatly reduced their financial support both for basic and applied research. Many research projects, such as detailed long-term studies of ecosystem development on stockpiled versus directly placed topsoil, are potentially very valuable. The state of our knowledge in the future will suffer if relevant research is not adequately funded in the present.

Aside from basic and applied research, has been the use by mine personnel of relatively new, untried techniques in an attempt to solve problems with their revegetation programs and to improve cost effectiveness. These "innovative practices" have been responsible for many important improvements in western surface coal mine reclamation, which are briefly described in the following subsections. Table 6 summarizes recent developments in revegetation technology, and the final subsection (2.9.11) briefly addresses the permit revision aspect of the new revegetation technologies.

2.9.1 Direct Haul or "Live" Topsoiling

The advantages of direct haul topsoiling have been demonstrated at many mines in the study area. Walsh & Associates (1985) also report favorably on this technique. The results of long-term studies of the effects of different methods of topsoil handling on revegetation have indicated that stockpiling can adversely affect the success of revegetation efforts. Studies that compare revegetation with stored topsoil versus directly hauled topsoil indicate that storing topsoil for more than baout 2 years at many sites significantly decreases the viability of included seeds as well as microbiota. At these sites, direct haul or "live" topsoil techniques preserve the biologically active component of the soil and tend to encourage faster re-establishment of nutrient cycles, significantly improving the establishment of planted and volunteer species and producing greatly superior lifeform and lifeform or species diversity within a relatively short time. The importance of maintaining a biologically active soil is not surprising when one considers that temperate-zone grassland and shrub-steppe ecosystems--those common in the study area--have substantially more biomass (i.e., living tissue) below ground than above ground. Furthermore, a good portin of the central ecosystem processes (nutrient cycling) are located below ground.

TABLE 6

SURVEY OF INDUSTRY INNOVATION AND EXPERIMENTATION AT STUDY AREA MINES

Experimental Topic	Examples of Use	Comments	Sources of More Information
1.0 SUBSTRATE Topsoiling strategies apparently affect postmine vegetation diversity			DePuit 1984
1.1 Direct Haul* Direct respreading of topsoil is now widespread due to economic and ecological advantages over stockpiling. Fresh topsoil is an excellent source of native seeds and other biota which accelerate revegetation and stabilization of the site and improves postmining diversity.	In use throughout all of the study area to extents allowed by the mine plans and operations. See companion report on soils/overburden.	Use limited in ND by need to return soil to original landowner.	Howard & Samuel 1979 Iverson & Wali 1982
2.0 PLANTING			
2.1 Using Local Seed Plant materials already adapted to the mine site provide maximum likelihood for short- and long-term survival and vigor. However, for practical reasons, local seed collection only occurs when important species are unavailable commercially or when local stock confers needed adaptability. Most local collection work focuses on shrubs. ponderosa pine stock needs to be locally adapted. Local seeds may be collected and planted as seeds, or in cases where wildland seeding establishment is problematical, may be grown in a nursery first and transplanted to the mine site.	Ponderosa pine seed: MT Powder River Basin, Case Studies (C.S.) MT-1, MT-2. Deciduous trees/shrubs: ND Ft. Union Basin, C.S. ND-1; MT Powder River Basin, C.S. MT-1. Shrubs: WY Hanna Basin, C.S. WY-4.	Unpredictability of wildland seed production is a limitation.	Murphy, ed. 1983

*These practices are now widely used and would not currently be considered innovative, but are included here because they were considered innovative in 1980.

TABLE 6 (cont.)

Experimental Topic	Examples of Use	Comments	Sources of More Information
2.2 Species Mix and Planting Rates			
A good seed mix takes into consideration postmining land use, competitiveness of the speices, topsoil handling, and mulching techniques. Total planting rate as well as the species mix will influence the intracommunity diversity of the revegetated lands. For example, decreasing the total planting rates on direct haul topsoil and increasing the amounts of warm season grass seeds increases diversity.	Most mines experiment with seed mixes and rates in order to address their site conditions.	See discussion below of lifeform and species diversity	
2.3 Native Transplants*			
Transplanting native woody plants at the mine site is now widespread due to ecological advantages such as provision of native seeds. Both front end loaders (with bucket modifications) and tree spades have been used to transplant limited numbers of shrubs and trees plus associated soil.	In use throughout all of the study area. C.S. CO-1 in northwestern CO is noteworthy for its work on native shrub plantings using a modified front end loader bucket.	Substantial expense limits use.	Bunin 1983
2.4 Dryland Sodding			
Transplanting grassland sod is desirable where erosion is a problem and is possible in limited situations where vegetation forms a dense, shallow root mat.	MT Powder River Basin, C.S. MT-1; WY Powder River Basin, C.S. WY-1.	Expensive, but a commercial sod cutter has been successfully used at C.S. MT-1 since 1977.	Bunin et al. 1982
2.5 Nursery Stock*			
Use of containerized nursery stock has been widely tested at study area mines.	Nearly all mines with wildlife habitat as a postmining land use.	Containerized nursery stock has generally proven to have low survival rates and high expense.	Crofts 1982
Use of bare root stock has been tested at some mines and used regularly at a few.	Northwestern CO, C.S. CO-1; ND Ft. Union Basin, C.S. ND-1; MT Powder River Basin, C.S. MT-1.	Bare root stock has somewhat higher survival than containerized stock when properly handled.	Stevens 1980 Crofts 1982 McKell & VanEpps 1981

TABLE 6 (cont.)

Experimental Topic	Examples of Use	Comments	Sources of More Information
3.0 LIFEFORM AND SPECIES DIVERSITY Diversity within a postmining plant community can be influenced by site preparation, planting, cultural, and management practices. Experimentation focuses on diversity effects of revegetation practices (also discussed in other parts of this table that focus on these practices one by one).			
3.1 Competition Avoidance to Improve Diversity Several planting schemes aim to improve warm season grass, shrub, and forb establishment by decreasing the usual competitive advantage of cool season grasses.			
In two-phase seeding, shrubs and forbs as well as warm season grasses are broadcast seeded along with a temporary cover crop in the first phase. After their — initial establishment, or one to three growing seasons later, the cool season grasses are interseeded.	First tried and adopted at C.S. MT-1 in the Powder River Basin. Now in use at other MT mines. Under test at WY Powder River Basin Mine C.S. WY-1.		DePuit & Coenenberg 1980 Coenenberg 1982
In delayed seeding plus irrigation, late spring to early summer planting with irrigation for establishment assists warm season grasses.	ND Ft. Union Basin, C.S. ND-1. At C.S. MT-1, discontinued due to irrigation disadvantages.	Irrigation water is scarce at many mines. Irrigation is costly.	Williamson 1984
3.2 Management and Culture to Improve Diversity Fertilization rates affect postmining plant diversity. Lower rates of nitrogen favor desirable natives and decrease weeds. On direct haul topsoil, no nitrogen fertilization can be advantageous.	Fertilization experiments have gone on at many mines. No fertilization of direct haul soils has been implemented at some mines, e.g., C.S. MT-2.	Need for fertilizer will vary from mine to mine and site to site.	Holechek et al. 1981 Doerr et al. 1983 Coenenberg 1982

TABLE 6 (cont.)

Experimental Topic	Examples of Use	Comments	Sources of More Information
Grazing, haying, burning, and herbicides have all been found to improve diversity under certain conditions. For example, in the Northern Great Plains, warm season grasses benefit from late spring burning, grazing, spraying, or haying due to decreased competition from cool season grasses and weeds.	Ongoing at a number of mines, including C.S. MT-1, ND-1, and in the WY Powder River Basin.		DePuit, Coenenberg & Skilbred 1980 DePuit 1982 Ries & DePuit 1984
3.3 Shrub Establishment*			
See the preceding discussions (2.3, 3.1) in this table. Due to concerns with restoring diversity and wildlife habitat there has been experimentation with seeding and transplanting shrubs at many mines. Many shrub seed characteristics (e.g., smallness) and lack of competitiveness with common grasses have necessitated the use of special procedures for their establishment. One common approach is to seed shrubs and plant nursery stock to provide seed sources.	Most mines in MT, WY, CO, and NM have experimented with shrub establishment.	Because of agricultural land use and the scarcity of upland shrubs, most ND mines have not been concerned with upland shrub establishment.	Murphy, ed. 1983 Stelter, et al., eds., 1981
Big sagebrush, the single most widespread shrub in the study area is also one of the hardest to establish from seed. It is also important for wildlife habitat restoration. Due to its vegetation, wildlife patterns, and regulatory requirements, Wyoming has been particularly concerned with big sagebrush establishment.	Many mines in MT, WY, CO, and NM have tried various procedures.	Seeding of big sagebrush remains unreliable at most mines, although direct haul topsoil improves reestablishment. Shallow seeding and use of adapted material has proven important.	Harniss et al., eds., 1981
Spatial separation of shrubs (often along with forbs and warm season grasses) and aggressive grasses has been investigated by combinations of broadcast and drill seeding or two-directional seeding.	C.S. CO-1 in northwest CO; C.S. WY-2 in the southern Powder River Basin.		

TABLE 6 (cont.)

Experimental Topic	Examples of Use	Comments	Sources of More Information
4.0 CULTURAL PRACTICES			
4.1 See 3.0 in this table concerning improvements in diversity.			
4.2 Mulch*			
The type of mulch and rate and method of application influences the effectiveness in retaining moisture and decreasing erosion.	Mines often experiment to see what works, e.g., C.S. MT-1 now crimps and does not rotavate mulch. Another MT mine is using a standing stubble mulch.		
The use of native hay mulches can provide native seed sources sometimes not easily available, e.g., needle-and-thread (*Stipa comata*). Some native hay has especially good mulch characteristics, e.g., sloughgrass (*Beckmannia syzigachne*).	MT Powder River Basin mines, including C.S. MT-1; C.S. ND-1; WY Powder River Basin mines, including C.S. WY-4.	Reliable sources are hard to find. Weed seeds can be a problem.	Reis et al. 1980 Darling & Young 1984
Use of "Rotoclear" machinery to concurrently clear woody plants, provide mulch material and facilitate more complete topsoil removal.	C.S. CO-1 in northwest CO; is experimental at a mine in northwestern NM.		
4.3 Preparatory Crops			
C.S. MT-1 has used wintergraze as a temporary cover crop in first-phase seeding. It establishes well, is short lived, and sterile. DeKalb no longer supplies it.	C.S. MT-1 in the MT Powder River Basin.	In most areas of dryland culture, preparatory or nurse crops have been deemed deleteriously competitive to perennial establishment.	
4.4 Water Harvesting			
Procedures to improve available water supply are various.	C.S. NM-1 in the San Juan Basin. C.S. MT-2 furrows on pine sites.		

TABLE 6 (cont.)

Experimental Topic	Examples of Use	Comments	Sources of More Information
4.5 Irrigation Systems			
A number of mines use irrigation to establish vegetation. At some mines the systems are still being improved. Northern Great Plains irrigation is for establishing warm season grasses.	C.S. MT-2: drip for pines; C.S. ND-1: traveler (sprinkler)	Lack of available water is a limitation at many mines.	Sherman & Sullivan 1980
Southwest Wyoming and northwest New Mexico irrigation is for initial stand establishment of all species.	C.S. NM-2; and southwestern WY mine.		
5.0 MANAGEMENT			
See 3.0 in this table.			
5.1 Rejuvenating Grasslands			
In the Northern Great Plains, litter buildup in grasslands can tie up nutrients, promote disease, and decrease live cover and productivity. Therefore, burning and grazing are being used to rejuvenate grasslands. See 3.2 in this table.	The most extensive use is at C.S. MT-1 and ND-1. Is under evaluation at WY Powder River Basin mines including WY-1.	Careful control of the burning and grazing is needed.	Coenenberg 1982
5.2 Fencing			
New Zealand electric wire is relatively inexpensive, easily moved, and can be supplied by its own solar unit.	C.S. MT-1.		
6.0 LANDSCAPE OR COMMUNITY DIVERSITY			
The establishment of diverse communities may be achieved by the use of one broad seed mixture or by use of more specialized seed mixes. Other practices to establish special plant communities are shown here.			
6.1 Ponderosa Pine Re-establishment			
To favor pine restoration, north-facing slopes are utilized, coarse soils are special handled, local seeds may be grown as nursery stock, competition from herbs may be controlled (e.g., by mulch or herbicides), and attempts may be made to protect the pines from winter rodent and deer activity. Skunkbrush sumac, which also prefers coarse soils, is sometimes an associated planting.	Since 1978 at C.S. MT-1 and MT-2. Also another MT mine.	Most mines do not have pre- or post-mine pine vegetation. C.S. MT-2 has been asked by MDSL to restore a closed canopy forest.	Stark 1982

TABLE 6 (cont.)

Experimental Topic	Examples of Use	Comments	Sources of More Information
6.2 Woody Draw Reestablishment To favor deciduous shrub and tree communities, sites are created with topography that catches and retains moisture, soil may be special handled, local seeds may be used to grow bare root stock, competition from herbs is controlled (e.g., mulch), and careful management is needed.	C.S. ND-1 has the most extensive areas. MT Powder River Basin mines including C.S. MT-1 and MT-2 are also restoring deciduous drainage communities.	Many mines do not have woody draws. Many ND mines avoid disturbing woody draws on the mine site.	
6.3 Wetland Reestablishment Restoration of wetlands in ND was first tried before the permanent regulatory program at one mine. Recently, restoration of prairie pothole wetlands, e.g., C.S. ND-2, is utilizing selective soil handling and transplants of wetland vegetation plugs.	ND Ft. Union mines, including ND-2.	Few mines need to address wetlands.	
6.4 Playa Reestablishment An internal drainage including a playa has been approved for C.S. WY-6. Clay-rich soil will be special handled and returned to playa.	C.S. WY-6.	A few other mines have proposed inclusion of closed depressions, but no special handling of clays.	

However, the efficacy of direct haul topsoiling varies between regions and sites within regions. The utility of this technique depends upon the premine soils and vegetation characteristics as well as the mine plan and requirements for the mine operation. Mine logistics can prevent the use of direct haul over much of the disturbed area (e.g., in deep or multiple seam operations). Direct haul may be logistically impossible at some sites for many years, or as in the case of North Dakota, scarcely applicable due to the requirement to return the soil to the original landowner.

Because the direct haul technique eliminates the middle step in the process of stripping, stockpiling, and respreading topsoil, it usually is less expensive. Direct haul also is advantageous for small mines that do not have room for topsoil stockpiles. The fortuitous coincidence of economic and biologic advantage has caused direct haul to be adopted to some degree by most western surface coal mines that are beyond the first box cuts. In some cases, the area ultimately treated by direct haul is well over 50 percent.

The practice of handling soils in "two lifts" can provide some of the same advantages as direct haul topsoil, depending upon the topsoil storage time and the depth of the lifts. Two lifts require that surface materials are kept segregated from subsurface materials during stockpiling or direct haul operations, and redressed with topsoils over subsoils. The surface soil, including the A horizon along with the upper B horizon, is the zone of maximum organic matter accumulation and microbiotic activity. The subsoil, consisting of the lower B horizon (if present) and the C horizon, contains far less organic matter, and can have a layer of calcium carbonate accumulation that reduces its value as a plant growth medium.

Two-lift soil handling is an especially important consideration in deep soils. When a soil suitable to depths as much as 60 inches is salvaged, the relatively thin surface layer of maximum biological activity is mixed with relatively sterile, albeit chemically and physically "suitable" subsoil, unless a two-lift method is employed. Lost by burial are roots, seeds, and beneficial microbiota, as well as the organic-rich surface material. Surficial organic matter that could increase soil moisture capacity and gas exchange and decrease erodibility is gone. Seeds and roots are distributed throughout a large soil volume, many buried too deeply to affect revegetation. Two-lift salvage is required in Montana and North Dakota and is standard practice at many other western mines.

Research on direct haul topsoil has revealed an instructive comparison between early and present revegetation technology in terms of plant ecology. The earliest revegetation efforts on bare mine spoil closely approximated primary plant succession in which plant life colonizes sterile mineral matter and, over a very long period, nutrient cycles develop slowly. More recent revegetation, using topsoiil, and especially that spread directly, closely approximates secondary plant succession in which the aerial parts have been destroyed but the soil portion continues to function. The difference between the two types of succession is great in the time required to return cover, production, and diversity to premining levels.

2.9.2 Newly Available Plant Material

During the last 10 years, the requirements for native species in SMCRA and some State laws have led to the commercial availability of an increasing variety of native seeds and seedlings. These new materials have resulted from the work of SCS Plant Materials Centers in the study region (Los Lunas, New Mexico; Meeker, Colorado; Bridger, Montana; and Mandan, North Dakota) and of private seed collectors and seed companies. The Plant Materials Centers have installed test plots at several surface coal mines to evaluate different genetic strains of desirable species collected from the region under a variety of realistic field conditions and selecting for vigor on harsh sites. After being selected by the Plant Materials Centers, seed of a particular variety is released to commercial production. The private companies generally use only seed collected in the field, although some is now coming from irrigated "seed orchard" plantings. Considerable progress has been made in the quality of native seed sources by basing the sale on a PLS (pure live seed) basis, which avoids the problem of inviable seeds and of plant debris or "trash" (Vallentine 1980).

Needs for additional native seeds still exist. For example, the lack of adapted blue grama grass for use in surface mine revegetation in the Northern Great Plains may explain part of the difficulty in re-establishing this species in that region.

Theoretically, the best source of seeds for revegetation is the local flora, which is already adapted to the site and provides maximum likelihood for long-term survival and vigor. For practical reasons, however, the mines that regularly collect local seed do so primarily for shrubs and trees. The strain-selected plant materials developed by the SCS usually are easier to establish and may have greater herbage production and disease resistance than the wild-collected materials, but they frequently represent a more limited portion of the gene pool of the species. The importance of maintaining genetic variability in revegetated landscapes has not received much attention, but it bears directly on the subject of permanence. A wider range of genetic variability may include strains pre-adapted to environmental extremes, insects, diseases, or substrates not present in a test plot situation but potentially encountered over the long-term life of a stand (Stutz 1982).

The SCS recognizes the importance of genetic diversity for long-term native seeding, as opposed to the desirability of genetic uniformity for agronomic purposes. This recognition is reflected in work on native grasses and shrubs at the SCS Plant Materials Center in Bismarck.

2.9.3 Minimizing Competition to Enhance Lifeform and Species Diversity

One of the problems in mine revegetation has been the establishment of required lifeform and species diversity for native rangeland and wildlife habitat. Of particular concern in early efforts was the tendency of various shrubs, forbs, and warm season grasses to either not germinate or not survive much beyond germination.

Ecological investigations have revealed that competition from aggressive cool season grasses, mostly introduced forage species but including some native species, often is the main factor contributing to the failure of the less aggressive seedlings to become established. Two remedies commonly used in recent years have been to reduce the relative proportion of the aggressive cool season grasses in the seed mix to offset their competitive advantage, and to use two-staged or two-phased planting to reduce competition by separating the aggressive and less-aggressive species. Another successful approach has been to plant late and use supplemental irrigation to allow warm season grasses to become established. Also, lower total planting rates associated with direct haul topsoil typically have improved the establishment of less aggressive species and diversity.

The use of two-staged or two-phased planting, first practiced at case study mine MT-1 in Montana, has attracted much attention and proven quite successful. As used at MT-1, the method consists of planting warm season grasses as well as forbs and shrubs into prepared topsoil and allowing one to three growing seasons to pass before interseeding with cool season species. This gives the less aggressive species a chance to become established before facing competition from the cool season grasses. A similar approach has been used at case study mine WY-2. Another technique has been used by some mines in northwestern Colorado, where sequential drill-seedings at an angle to one another provide a small but apparently effective separation of aggressive from less aggressive species.

In North Dakota at case study mine ND-1, warm season grasses have been successfully established for 6 years by planting in late rather than early spring and using supplemental irrigation. As in the cases described above, planting cool season grasses during the warm season reduces their competitive advantage, while the supplemental irrigation maximizes the growth of the warm season species.

2.9.4 Minimal Fertilization

The role of fertilization in surface mine revegetation has steadily diminished as pasture species dependent on high fertilizer rates have been replaced by native species in seed mixes. Application of fertilizer, particularly nitrogen, to young stands of native species tends to encourage vigorous growth of weeds, introduced species, and the more aggressive native grasses to the detriment of the less aggressive natives (including woody plants) which usually have lower nitrogen demands. Fertilization of direct haul topsoil has likewise been found to diminish diversity by favoring a few species at the expense of others.

2.9.5 Management of Grasslands

Several special management techniques are being used on upland grasslands in the Northern Grat Plains to improve lifeform and species diversity (particularly warm season grass establishment) and vigor. In these areas, grassland comprised of highly productive species may become stagnant if excess litter accumulates, because litter ties up nutrients and can promote disease. Grazing is one technique for breaking up the litter and incorporating seeds and organic matter into the soil. Burning can also increase nutrient availability temporarily and hasten breakdown of the litter. Grazing, burning, haying, and herbicides may improve diversity (including seasonality) by decreasing the competitive advantage of cool season grasses and undesirable "weeds." Thus, at several mines in Montana and North Dakota (e.g., MT-1 and ND-1), these management practices are carefully conducted at certain times of the growing season, usually in late spring.

While many ecologists view grazing as necessary for the health of grasslands in the Northern and Central Great Plains (e.g., see DePuit et al. 1980, Coenenberg 1982), this apparently is not the case for semi-arid grasslands of the southwest, which have different responses to grazing pressure (e.g., Sims et al. 1978).

2.9.6 Technology of Shrub Establishment

The technology of shrub establishment has been a major area of research and innovation since SMCRA. In the first few years after SMCRA was passed, emphasis was placed on the use of live plants. This was prompted to a large degree by the general failure of woody plants to successfully establish from seed. The live woody plants were of three types: containerized stock ("tubelings"), bareroot stock, and direct transplants from native stands in the mine area.

Containerized stock showed promise earlier in western reforestation programs, and application of the technique to shrubs was enthusiastically pursued by government and private industry. For example, containerized stock was recommended for use in the Northern Great Plains to establish evergreens (Orr 1977, Bjugstad et al. 1980) as well as other species (Jensen and Hodder 1977) and for use in Utah to establish shrubs (McKell and VanEpps 1980). The use of containerized shrub stock has been somewhat hindered by low survival rates and consequently high costs per surviving stem as indicated in trials at some mines (e.g., Crofts 1982).

Bareroot stock has proven to have higher survival rates and more favorable costs, but bareroot stock is available for only a limited number of suitable species, and the period suitable for field establishment is limited. Bareroot stock has been recommended by Orr (1977) and Bjugstad et al. (1980) for establishing deciduous species and by Crofts and Parkin (1980) for general use.

Direct transplants have proven feasible at several mines, using front end loaders with standard or specially modified buckets. The relocated masses of soil and plants are typically used to establish islands of native shrubs, soils, and accompanying herbaceous species, from which volunteers may radiate, vegetatively or from seed. Use of this method to directly establish required stem densities may not be practicable, however, at mines with high shrub density replacement standards.

Shrub establishment technology has essentially come full circle from initial rejection of direct seeding to its acceptance as the major means of effectively and economically achieving the required woody plant densities. Improvements in the success of direct seeding have resulted largely from the recognition that the shrub seedlings must be protected from competition by the aggressive cool season grasses that are planted to control erosion and to support grazing. This separation is less important in the most arid parts of the five-state study region, because of the lower vigor of herbaceous growth. Also important is the improved availability of seeds for a variety of native shrub species.

The use of direct haul topsoiling has proven especially favorable for shrub establishment in some areas because of the presence of viable shrub seed and of live roots that for many species can sprout new growth. Sites that have been reclaimed by the direct haul method often show promise of excellent shrub establishment with little or no supplemental seeding, although this depends to a large extent upon the particular shrub species involved.

2.9.7 Mulching

The use of mulch to conserve soil moisture and aid erosion control has long been an integral part of coal mine revegetation technologies. While mulch is effective in erosion control, it often is difficult to anchor in windy regions. Also, the usual anchoring process of "crimping" the mulch into the soil may increase soil moisture loss by wicking.

Another problem is that straw or hay mulches tend to contain the seeds of undesirable species, and resultant weed infestations can cause serious competition with the planted species. Native hay mulches have been used successfully at several mines in the study area (e.g., ND-1 and MT-1). These mulches not only have been relatively weed free, but they also have contained the seeds of desirable but commercially unavailable species, such as needle-and-thread (Stipa comata) and prairie junegrass (Koeleria macrantha), and therefore improved diversity. However, reliable sources of native hay are scarce.

Another innovative approach developed by the USDA-ARS High Plains Research Station in Cheyenne, Wyoming, is the use of "stubble mulch," which starts with a cover of small grain drill-seeded in spring (Schuman et al. 1980). As the grain develops, the roots and basal leaves help retard water erosion while the vertical stems help reduce surface wind speeds, thereby reducing wind erosion and desiccation. During the winter, the remaining stubble helps to increase soil moisture by enhancing snow retention. Thus the perennial mix, which is interseeded into the small grain crop the following fall, germinates and grows in a more favorable environment than if the grains were not present. Plants commonly used as stubble mulch include winter wheat, spring wheat, barley, ryegrass, and Siberian millet, which generally are mown before they set seed to prevent undue competition with the perennial species in subsequent years. The problem of later competition also may be avoided by using sterile wheat-wheatgrass hybrids.

The use of mulch has proven unnecessary or counterproductive in some locations and situations. In New Mexico (case study NM-2), for example, irrigation obviates the need for mulch, and the regulatory authority has approved its omission on low slopes (<10 percent) where erosion control is not critical. In more favorable climates, such as the Powder River Basin, some experimental data show an eventual advantage to omitting mulch (e.g., at case study mine WY-1).

A development in northwestern Colorado has been the use of locally produced mulch (case study mine CO-1), where woody plant cover in mountain shrubland or aspen forest is treated before topsoil removal with a tractor-mounted shredder that leaves a residue of finely chopped woody biomass on the soil surface. This method is used in conjunction with direct haul topsoiling and allows more complete salvage of the most valuable surface soil that might otherwise be lost during bulldozer removal of woody vegetation. After topsoil removal and replacement on the reclaimed surface, sufficient organic debris remains on the surface to function as a mulch. This technique was approved in lieu of mulch in certain areas of northwestern Colorado by the Colorado MLRD and is now under experimental use at a mine in northwestern New Mexico where the vegetation is sagebrush shrubland and pinyon-juniper forest. This method has promise in many areas but has yet to be fully evaluated outside northwestern Colorado.

2.9.8 Irrigation

The goal of revegetation for native rangeland and wildlife habitat land uses is the establishment of a self-sustaining plant community, which would preclude long-term irrigation. However, the period of germination and initial seedling growth is critically dependent on the availability of adequate moisture. Early concern about revegetation in areas with less than 10 inches of annual precipitation led to the assumption that successful revegetation in such areas would require irrigation (e.g., see National Academy of Sciences 1974). In southwestern Wyoming, this assumption was reflected by permit stipulations for irrigation at a number of mines. The invalidity of the assumption regarding the need for irrigation is illustrated by case study mine WY-3, where use of irrigation had to be postponed until either a suitable water source could be located or proof could be provided that the salty water available would not ruin the topsoils. While both the search for better water and studies of the effects of salinization continued, revegetation was attempted without the use of supplemental irrigation. Results to date show values of cover and production roughly comparable to the performance standards. Within the past year, the mining company cited these monitoring data in an attempt to be relieved from the stipulation to irrigate. Relief was granted for the duration of the 5-year permit but may be reinstated at the time of permit renewal.

Another example that casts doubt on the value of sustained irrigation is in northwestern New Mexico, which receives as little as 6-8 inches average precipitation. Case study mine NM-1 in this area waters for 2 years after seeding but has found that the plant biomass developed under irrigation suffers a substantial dieback during the third year, when irrigation is withdrawn. It has been suggested that vegetation developed more slowly under dryland conditions might provide the same levels of cover and production as initially irrigated vegetation by the end of the liability period.

Experimental dryland revegetation is being initiated at another nearby mine owned by the same company as NM-1.

2.9.9 Landscape Diversity

One of the recent advances in revegetation has been the application of an ecological perspective in the establishment of a more diverse postmining landscape. All five states provide examples of mines that have used specialized seed mixes, such as distinct bottomland and upland mixes better suited to moist versus dry postmining substrate conditions.

Some of the most innovative work on landscape diversity has been conducted in the northern parts of the study area, as illustrated by case study mines MT-1, MT-2, ND-1, and ND-2. Special types of plant communities being restored at these mines include ponderosa pine forests, woody draws, and wetlands. Restoration of ponderosa pine communities in Montana has utilized separate handling of coarse soils, particularly those containing abundant rock fragments, and preferential re-application to north-facing slopes on the reclaimed surfaces. This relates to the fact that ponderosa pine require a substrate that is well drained but sufficiently moist to enhance early establishment. Nursery stock grown from local seed has proven most effective, with mulch or herbicides used to reduce competition from herbaceous species. Winter predation by rodents, rabbits, and deer is a continuing cause of mortality. The oldest plantings in 1978 have resulted in ponderosa pines 2-3 feet tall at case study mine MT-2 at the time of this report.

Re-establishment of woody draws includes deciduous tree and shrub communities in both Montana and North Dakota. Because these species require abundant soil moisture, the restoration process begins with the creation of topographic features to retain moisture, and sometimes the special handling of soils to return those with proper water-holding qualities. Mulch has been used to control herbaceous competition, and local seeds have been used when feasible. Case study mine ND-1 has a well developed restoration program now 7 years old which includes clustering specific woody species in portions of the drainage having the most favorable moisture regime. The long term success of the re-established woody draws will be interesting to monitor because all the steps being taken may not fully replace the lost moisture-supplying qualities of the coal seam, which is removed by mining and the moisture conducting properties of which apparently are partly responsible for the presence of the woody vegetation (Shatton 1985, pers. comm.).

Revegetating recreated wetlands appears relatively easy to accomplish, due in part to the ability of many wetland species to spread vegetatively from rootstock or cuttings. The program at case study mine ND-2 includes special handling of soil and transplanting of native vegetation "plugs" from nearby wetland areas. Although young, the restored wetlands already support good vegetation growth.

2.9.10 Revegetation Equipment

One of the circumstances restricting western revegetation in the early years was the unavailability of equipment designed for certain key tasks. Fortunately, the need for forest and range rehabilitation equipment was recognized during World War II, when the desirability of increased cattle and sheep production on National Forest lands spawned the Reseeding Equipment Development Committee in 1945. This group later became the Range Reseeding Committee and, ultimately, the Vegetative Rehabilitation and Equipment Workshop (VREW). Its membership has drawn heavily from government land management agencies but since the 1970s has included mining industry personnel. In the 1960s, the USFS established Equipment Development Centers in Missoula, Montana, and San Dimas, California, which cooperated with VREW in equipment development.

Perhaps the most significant piece of equipment to come out of this process has been the rangeland drill. The basic design was made in 1952 for reseeding depleted range on public lands. It proved to be a durable design and was quickly utilized for western surface mine revegetation. Besides needing structural strength to survive use on rough, regraded surfaces, the drill increasingly needed the ability to meter a wide variety of seed sizes and shapes. Other versions of rangeland drills have been developed by private enterprise during the past 10 years, and several are now widely used. They are the basic revegetation tool at most mines. A variation on the rangeland drill that combines seeding with the creation of surface depressions for moisture retention is known as the Hodder Gouger. Other surface treatments designed to catch water have been used at some mines (see Larson 1980).

2.9.11 Permit Revisions Involving Revegetation

Approval of innovative or other changes in revegetation practices after a permit has been issued follows a similar procedure throughout most of the five-state study area, although specific approaches depend upon the nature of the change. Generally, written approval is required for changes in seed mixes or substantial changes in management or cultural practices such as grazing practices and the use of irrigation. Changes in the range of normal cultural practices that were included in the permit application would generally not require written approval, such as in use of mulch, nurse crops, and fertilizers.

The time required for approval of revisions can vary considerably, depending upon the level of controversy over the change and the workload of the regulatory authority. The range of typical times for approval is from a few weeks to several months for changes in revegetation practices. Major changes involving more than just revegetation practice are handled through different regulatory procedures and can take considerably longer. For instance, in Montana, it has taken about one year for approval of a postmining land use change from rangeland to cropland.

SECTION 3.0

CASE STUDIES

3.0 CASE STUDIES

3.1 SELECTION CRITERIA

Case studies were chosen in consultation with OTA staff and based on recommendations of State regulatory personnel and a variety of environmental groups. Case studies were selected that would (1) encompass a wide range of environmental conditions within the five western coal producing states, including both high and low precipitation regimes and different types of substrate and topography; (2) involve different mining technologies, such as dragline versus truck and shovel; (3) represent a number of different post-mining land uses, including wildlife habitat, native rangeland, improved pasture, and cropland; and (4) reflect varying revegetation ages, revegetation techniques, and standards of revegetation success. Preference was given to mines with Federal coal on non-Indian lands for which revegetation monitoring data were available or where innovative techniques had been employed. Abandoned mine lands were excluded from the study.

A total of eleven mines were chosen as case studies. Nine additional mines were used as partial case studies, to examine particular revegetation practices or permitting issues not reflected in the eleven full case studies.

3.2 FULL CASE STUDY SYNOPSES

Full case study mines included two in Colorado (CO-1, -2), one in Montana (MT-1), three in New Mexico (NM-1, -2, -3), one in North Dakota (ND-1), and four in Wyoming (WY-1, -2, -3, -4). The results of the full case studies are summarized in the following subsections. The revegetation seed mixes used at these mines are presented in Appendix B.

3.2.1 Colorado

3.2.1.1 Case Study Mine CO-1. This mine was chosen to represent mines in the Sand Wash Basin in the northwestern part of the state and because of its use of innovative revegetation practices. The mine includes both pre-SMCRA and post-SMCRA revegetation.

This is among the highest elevation surface coal mines in the region, being located between about 7,200 and 7,700 feet. The elevation is reflected both in moderately high annual precipitation (16 inches) and the presence of Aspen and Mountain Shrub vegetation mapping units (termed "range sites" in the permit application baseline report). Other mapping units were Big Sagebrush, Low Sagebrush, Treated Sagebrush, Silver Sagebrush-Meadow, Meadow, and Pastureland. Vegetation mapping was done at a scale of 1" = 500' (1:6000).

Premining land uses in the permit area were native rangeland, pastureland, cropland (hay), and mined land. Postmining land uses are the same.

Baseline vegetation studies were conducted in 1979 by mine personnel. Sampling design used random numbers identifying map grid cells, with quantitative data collected as follows: Cover--absolute cover by species using the placements of a 10-point frame along a 50 m transect; Production--herbaceous and shrub growth (to 4 1/2 feet) clipped in 0.25 m^2 plots, results expressed as g/m^2 and lbs/acre; Woody Plant Density--point-centered quarter plotless method, later supplemented by 1 m x 50 m or

2 m x 50 m belt transects. The species/lifeform diversity calculation was based on Shannon-Weaver and McIntosh numerical indices.

The revegetation performance standards are to be established by reference areas for cover and production, and have been negotiated at 1,000 stems/acre with no more than 40 percent sagebrush for woody plant density. The diversity standard calls for a maximum of 57 percent relative cover to be provided by up to three species combined, with no more than 42 percent relative cover contributed by a single species.

Reclamation methods consist of direct haul wherever possible, with about 90 percent of the area currently subject to this technique, and topsoil replacement to a depth of 22 inches. The seedbed is prepared by chiseling on the contour, care being taken to not uproot volunteer seedlings and root sprouts. Three seed mixes are used: a rangeland mixture of fourteen grasses, ten forbs, and seven shrubs; a pastureland mixture of eight grasses and two forbs; and a cropland (i.e., hayland) mixture of four grasses and one forb (all introduced) (see Appendix B). All three mixes are seeded at the rate of 12 PLS lbs/acre.

Seeding is conducted in the fall using a rangeland drill, with grasses seeded at an angle to the direction of forb and shrub seeding. In addition to the shrubs included in the rangeland mix, woody species also have been planted as containerized and bareroot stock (the latter proving ineffective) or as on-sire transplants using a front end loader to establish "islands" of plants and soils.

Cultural and management practices include the use of mulchin the form of wood chips generated before topsoil salvage by shredding trees and shrubs. The residue of shredded wood is sufficient following topsoil replacement to function as a mulch. In some areas, a cereal grain may be planted as a preparatory or "nurse" crop. The revegetated areas are not fertilized or irrigated, although contour furrowing is used to conserve surface runoff. Revegetated lands are to be grazed for at least two years prior to bond release. Wildlife control has not yet been practiced, but heavy predation by big game on woody regrowth, especially aspen, has necessitated an upcoming experimental program of protective fencing.

Revegetation data are collected annually for cover using ten placements of a 10-point frame along 50 m transects, production by clipping five 0.25 m^2 plots along 50 m transects, and woody plant density by counting all individuals within 1 m x 50 m or 2 m x 50 m belt transects.

Mine CO-1 has been responsible for a number of innovations, applying sound ecology to improve diversity and relieve engineering and construction constraints. Major innovations (described previously) include (1) the use of "Rotoclear" machinery to concurrently clear woody plants, provide mulch material, and salvage topsoil otherwise lost on woody plant roots; (2) the direct transplant of woody plants using a specially modified bucket for a front end loader; and (3) the use of "live" (direct haul) topsoiling to quickly re-establish vegetation cover, with supplemental seeding often being unnecessary (but nonetheless required by the State).

3.2.1.2 Case Study Mine CO-2. Located in the North Park area of northern Colorado, this mine began operation recently enough that all reclamation is post-SMCRA. Besides its geographic location, CO-2 was selected because of its relative aridity for Colorado surface mines (about 10 inches) and its mining technique (scraper-loader-truck).

Elevations of the permit area average about 8,300 feet, with premining vegetation listed as Sagebrush-Grass, Sagebrush-Gravel, Treated Sagebrush, and Alkali Sagebrush. Premining and postmining land uses are reported as (native) rangeland.

Vegetation mapping was done at a scale of 1" = 500' (1:6000). Baseline data collection was conducted in 1980 by mining company personnel who used a sampling design of random numbers identifying cells on a map grid. Quantitative sampling was accomplished using ten placements of a 10-point frame for absolute herbaceous cover and a 50 m line intercept for absolute shrub cover; clipping herbaceous and annual shrub growth in 0.25 m^2 plots for production, with values expressed as g/m^2 and lbs/acre; and total counts of all woody plants within 1 m^2 plots for density. Diversity was determined by enumerating the total species (i.e., richness) and calculating a Shannon-Weaver index for each vegetation type.

Revegetation performance standards are to be established based on reference areas for cover and production, a negotiated woody plant density of 2,000 stems/acre, and a target diversity of four species providing between 3 and 40 percent relative cover each.

Reclamation has not included direct haul to date, although it is planned for later. Topsoil is replaced to a thickness of 6-9 inches, underlain by 0 to 27 inches of subsoil. The ground surface is prepared for seeding by chiseling and discing as necessary. One seed mix is used, which consists of thirteen grasses, seven forbs, and four shrubs, seeded at the rate of 14 PLS lbs/acre (Appendix B). Of the shrubs, winterfat and antelope bitterbrush, both of value to wildlife, have established poorly to date, and the company would like to test woods' rose. Three forbs--small burnet, Lewis flax, and western yarrow--have done well.

Seeding is done in the fall using a rangeland drill, with grasses planted on the contour and forbs and shrubs in rows perpendicular to the contour to provide spatial separation. Nursery stock is used to supplement woody plant seedings.

Cultural practices include an annual ryegrass preparatory crop, later mown to provide a "stubble mulch." Irrigation is not used, but contour furrowing helps to preserve surface runoff. The BLM has completed a 5-year study of mulches and snowfences on site as a means of increasing spring soil moisture. Oddly, their results are not being made available to the mining company. Fertilizer is not applied to the revegetated areas.

Management practices include weed control as necessary, Canada thistle apparently posing somewhat of a problem. Grazing is planned for later in the liability period. Wildlife damage reportedly is not a problem except occasionally from rabbits.

Revegetation data collection includes cover, production, and woody plant density, with diversity calculated from the cover data. Not all areas are sampled every year.

3.2.2 Montana

The only full case study mine in Montana (MT-1) was selected on the basis of its geographic location in the northern Powder River Basin, the presence of both pre-SMCRA and post-SMCRA reclamation, a large area of revegetation, and the use of numerous innovative practices. The mine operated from 1924 to 1958 and then reopened under new ownership in 1968. A comprehensive mine plan that incorporated the prior applications (dating to 1973) was submitted in 1981.

The mine is located at 3,200-3,700 feet elevation and receives an average annual precipitation of about 16 inches. Vegetation mapping was done at a scale of 1" = 400' (1:4800).

Eight native vegetation types were identified within the premining land uses of native rangeland and wildlife habitat. These were Upland Grassland, Big Sagebrush-Grassland, Silver Sagebrush-Grassland, Deciduous Tree-Shrub, Riparian/wetland, Ponderosa Pine, Skunkbrush Sumac, and Mixed Shrub as well as Cropland. The premining and postmining land uses are native rangeland, wildlife habitat, and cropland.

Baseline vegetation studies were first conducted in 1972. Studies in the current permit application were carried out in 1980-1981 by consultants and company personnel.

Sampling design was based on random numbers identifying map grid cells. Quantitative data were collected as follows: Cover--absolute and relative cover by species and lifeform in seven cover classes collected in 0.1 m^2 plots; total vegetation, rock, and litter also reported; frequency and constancy calculated; for trees and shrubs, additional cover data taken by the line intercept method. Production--herbaceous plants by lifeform clipped in 0.5 m^2 quadrats; woody plants measured by microunit method (in which one leader is clipped, all leaders are counted, and these numbers multiplied to estimate a total); results expressed in g/m^2 and lbs/acre. Woody Plant Density--shrub data by direct counts within belt transects; tree data collected in 1 ha plots; results expressed in stems/ha and stems/acre. No diversity calculation was included in the permit application.

The revegetation performance standards are to be established by reference areas. Currently, legal requirements are that woody plant density and weighted cover, production, and lifeform or species diversity in the revegetated areas be comparable to that of reference areas, i.e., 90 percent of the reference area value with 90 percent confidence for herbaceous vegetation and 80 percent confidence for woody vegetation. In fact, current MDSL performance standards are under review and changes are expected.

Topsoil is direct hauled to the extent practicable (most of the area), or else stockpiled and stabilized with the steep uplands revegetation mixture and/or mulched. This mine pioneered and continues to use a two-phase seeding procedure in which hard-to-establish species are planted in a first phase that is later followed by a second phase seeding of cool season grasses.

The seedbed is prepared for the first phase seeding by ripping the spoil (to bind topsoil) as needed, then chisel plowing or discing, usually on the contour (to reduce topsoil clods). For the second phase, a surface seedbed scarifier is used to loosen the soil surface.

Five non-agricultural seed mixes are used for the second phase seeding in five respective postmine management units: Uplands, Lowland/Drainage, Wetland/Riparian, Steep Uplands (slopes greater than 10h:1v), and Conifer Zones. The same first phase or supplemental grass, forb, and shrub mix is used for all the postmine management units.

The "supplemental mixture" contains thirteen species plus a temporary cover crop species (see Appendix B). Of the thirteen, four are grasses, two are shrubs, and seven are forbs. Two forbs that are used in minor amounts are introduced legumes. Two of the grasses are warm season species. The first phase "supplemental mixture" also includes additional indigenous species (see the two lists in Appendix B) depending upon their availability and appropriateness for the management unit. For rehabilitation of shrub types, the appropriate shrub seed is included in the supplemental mix. The Uplands and Steep Uplands postmine management mixes each contain four grass species, the Lowland/Drainage mix seven grass species, the Conifer Zone Grass mix five grass species, and the Wetland/Riparian mix three grasses plus a number of sedge species. All the second phase mixes are seeded at a rate of 20 PLS lbs/acre. In the first three management units (Upland, Steep Upland, Conifer), four warm-season grass species are "patch seeded" on selected postmine sites of one acre or less to simulate seeding natural warm season grass communities. The rate is 40 PLS lbs/acre.

Croplands are seeded to alfalfa at 46 PLS lbs/acre for 5 years followed by winter wheat planting after 5 years.

Seeding times are early spring (mid March to late April), early fall (late August to late September), and late fall (mid October to end of November). Seeding of the second phase follows the first phase by one to three growing seasons depending upon vigor of the first phase.

The first phase seeding is broadcast with a Cyclone seeder and/or Brillon Sure Stand seeder. If it is Cyclone seeded, a cultipacker is used to firm the seedbed and cover the seed. The second phase is drilled with a Brillon seeder and/or Cyclone seeder. Croplands are drill seeded.

For desirable woody plants not commercially available, seeds are collected annually from native indigenous stands and sent to a greenhouse for propagation and later use as containerized stock. The same approach is used for some species of forbs and half-shrubs. Some trees and shrubs also are planted from nursery stock.

Tubelings are planted in appropriate upland postmine management units at a rate of 50-100/acre. In lowland and riparian sites, both bare root and containerized stock may be used. On-site transplants with a tree spade have been tried but have been little used. Transplants of native grassland sod have been used successfully to control erosion along the bottoms of reconstructed drainages.

Cultural practices for the non-agricultural lands routinely include mulching at the first phase seeding, and use of a temporary cover crop with the first phase supplemental mix. On slopes of 10h:1v or greater, native grass hay or wheat straw is disced or crimped at 1 1/2 tons/acre after chisel plowing. On slopes of 7h:1v or greater (such as highwalls) hydromulch is applied after seeding at 1 ton/acre. The temporary cover crop is wintergraze at 5 PLS lbs/acre or barley planted with the first phase supplemental mix. Preparatory crops such as winter wheat or barley are used when conditions are unsuitable for perennial planting. On cropland, oats or barley are used for spring planting. After harvest, alfalfa and pubescent wheatgrass (A. tricophorum) may be seeded.

Fertilization and irrigation are done as little as possible and only where needed. Irrigation may be used to establish warm season grasses, new transplants, and hard to establish trees, shrubs, and forbs. Interseeding is done as needed, especially in conjunction with burning.

Management practices are viewed at this mine as tools to improve the diversity and vigor of the revegetated lands. Weeds are controlled as necessary, especially by burning or mowing. Mowing and clipping are done in many young stands to decrease competition from undesirable species. Controlled burning has also been found to improve seasonality and diversity at this mine, as has controlled grazing beginning 2-3 years after the second phase of seeding. Revegetated lands are to be grazed for at least 2 years prior to bond release. To protect young nursery stock, wildlife access to coulee plantings and ponderosa pine plantings are controlled with fences as needed.

Postmining data from revegetated areas includes annual cover, production, and woody plant density data starting about 2-3 years after second phase seeding. Density data are taken yearly before starting the preceding regular program. Utilization data are taken on areas being grazed.

This mine has been very active in research and innovation for over 15 years. Work has included studies of topsoil depths, surface manipulation, native species, legumes, time of seeding, shrub re-establishment, sodding of native grasslands, temporary stabilizer, native hay mulch, and fertilization. Most of these studies were in cooperation with Montana State University. Work on pine re-establishment, new studies of coulee bottom restoration, and special soil handling for re-establishment of landscape diversity are summarized here.

Ponderosa pine studies have been ongoing since 1978. Current work utilizes selective handling of coarse soil materials in response to a recent permit stipulation from MDSL, but the coal company points out that pines have been successfully re-established without special soil handling in 6 years of cooperative work with the University of Montana School of Forestry. A well-drained site is important for pine establishment. Other requisites are that competition must be controlled by mulch or other means and that the plant materials be of local origin. Winter foraging on the pines by wildlife also is frequently a problem that must be controlled.

Coulee bottom restoration was specifically addressed by the coal company in response to a permit stipulation. The restoration plan calls for moderately steep, concave sites with north to east aspects to be planted with woody species at a spacing of 6 feet. Prior to this, a heavy straw mulch (5-7 tons/acre) will be applied to the replaced topsoil, with deep ripping on the side slopes. Bare root and containerized stock to be planted in the spring will include eight shrub or tree species. The drainage bottom and the steep sideslopes will receive plantings of appropriate species. After establishment is assured, the areas will be hand seeded to the lowland drainage seed mix in the bottom areas and the upland seed mix on the side slopes at 15 PLS lbs/acre. A monitoring program and careful management will be carried out.

3.2.3 North Dakota

The only full case study mine in North Dakota (ND-1) was chosen for several reasons: location in the Fort Union coal region, the fact that it is an old mine (opened in 1965) with extensive areas of both pre-SMCRA and post-SMCRA revegetation, the use of innovative practices, and its diversity of land uses.

This is one of the lowest elevation mines in the study area, lying between 1,900 and 2,100 feet, and also one of the most northerly. It receives an average annual precipitation of 16 inches. The diverse land uses and vegetation at this mine reflect the generally favorable growing conditions found in its vicinity as compared to the rest of the study area. Vegetation mapping based upon range sites was done at a scale of 1" = 400' (1:4800) with more detailed mapping of the woody draws.

Within the four primary categories of vegetation are a total of 16 types:

- Grassland: Subcategories within grasslands are by range sites. Major range sites are Silty (bluegrass/needle-and-thread), Sandy (prairie sandreed/needle-and-thread/Kentucky bluegrass), Shallow (little bluestem/needle-and-thread), and Thin Claypan (western wheatgrass/blue grama). Minor range sites are Sand, Thin Sand, Saline Lowland, Claypan, Clayey, Very Shallow, and Badlands/Clay Buttes.
- Woody Draws: Subcategories within Woody Draws are Mixed Deciduous Woodlands, Tall Shrublands, and Low Shrublands.
- Tame Pastureland/Hayfields
- Cropland

Premining and postmining land uses are native rangeland, wildlife habitat, tame pastureland/hayfields, and cropland.

Baseline vegetation studies for the post-SMCRA permits were conducted between 1979 and 1981 by consultants and company personnel. Sampling design was random. Quantitative data was collected as follows: Cover--in major rangeland types, basal cover by species and lifeforms using 10-point frames; frame held at 45 degree angle, which yields cover data that are high as compared to vertical projection of points; included total vegetation + rock + litter. All sites including minor rangeland types inventoried for species present, density of vegetation in 1/8 m^2 quadrats, and frequency. In woodlands, herb species presence/absence data in 1 m^2 quadrats provide frequency data; total herbaceous cover, woody cover in herb layer, litter, bare soil, and rock. Production--in major rangeland types, major grasses clipped by species and other plants by lifeform in 0.25 m^2 square quadrats; results expressed in g/0.25 m^2 and lbs/acre. Range condition also noted. Woody Plant Density--in woodlands, used nested quadrats: for trees (10 m x 10 m), tall shrubs (4 m x 4 m), low shrubs (2 m x 2 m). Results expressed as stems/ha and stems/acre.

Diversity was not calculated as part of application with the exception of woody draws, where it was expressed as number of species per square meter.

No revegetation standard system was accepted by NDPSC, with the exception of technical standards for woody plant density in the woody draws (the use of reference areas for grassland and SCS data for hayland and cropland was proposed in the 1983 repermit application). The technical standards for woody draws differentiate between three woody communities. Woody plant density in mixed deciduous woodlands is to be 3,745 woody plants/acre in year 10 of liability period, of which 1,315 are to be trees and 2,430 are shrubs. In the tall shrub type the standard is 8,100 shrub stems/acre in year 10 of liability period. In the low shrub type the standard is 10,800 stems/acre in year 10 of liability period. Also, 80 percent of the designated density number standard must have been in place for at least 8 years and 20 percent must have been in place at least 2 years.

In all the woody draws, a diversity standard requires that all species planted must be present at the end of the liability period. For each species planted, at least 50 percent of the initial number planted must be present at the end of the liability period.

Reclamation methods include stockpiling topsoil with very little direct haul possible due to the land ownership patterns and the requirement for return of the original topsoil to the landowner. The stockpiles are stabilized with a hayland seed mix and mulch. The topsoil replacement depth is a minimum of 10 inches with a minimum of total suitable plant growth material of 32 inches. Seedbed preparation consists of scarifying the spoil prior to replacing the suitable plant growth material. Discing, cultivating, harrowing, and conditioning are done as needed.

Three seed mixes are used. The grassland mix has twelve grass species and one forb and is applied at a total rate of about 22.5 PLS lbs/acre. The forb is an introduced legume species. Nine of the grasses are warm season species. Composition of the grassland mix has been changed from earlier permit applications to improve the diversity and seasonality of the revegetated grasslands. The tame pastureland/hayfield mix has four grasses and one forb species applied at a total rate of 13 PLS lbs/acre. The cropland mix has two grasses and two forbs applied at a total rate of 12 PLS lbs/acre (see Appendix B). After five years, croplands are seeded to a suitable variety of wheat and farmed intermittently (with summer fallowing) throughout the liability period.

In the woodlands, bare root stock of trees and shrubs is planted at a density of 2,700 stems per acre. The stock is grown from seeds collected locally as much as possible. Woody species used are shown in Appendix B. Woodlands have ten species, tall shrub communities seven species, and low shrub communities three species being planted. A tree spade has been used experimentally for direct transplants but has not been employed on a routine basis. Otherwise, planting uses a furrow-type planter.

Seeding times are in the spring or fall: in spring prior to June 1 or in early June if irrigation is available; in fall either early, August 10 to September 10 if soil moisture is adequate, or later, after October 20, if not. Seeds are drilled; machinery equipped to handle different size and weight seeds is used to plant the grassland mix.

Cultural practices for the grasslands include the use of native hay mulch as available. Needlegrass hay has been found to improve diversity from volunteers. On slopes up to 10 percent, 1 ton/acre or more of straw or hay is crimped into the soil. On slopes greater than 10 percent, 2 tons/acre of straw or hay are used. In woodlands, sloughgrass hay or wood chip mulch is utilized at 5 tons/acre, with the hay crimped into the soil. Mulch isused heavily in woodland sites, sometimes with the addition of an organic tackifier, to minimize soil erosion and herbaceous competition. Preparatory crops are used as needed. Typically this involves overwintering with rye, killing it in the spring with herbicide, and interseeding the permanent seed mix. Fertilization is done only as needed, with the intent to minimize the application of nitrogen.

Irrigation is used during the first growing season only if necessary and available. It is utilized particularly to improve seasonality in combination with late spring planting of the grassland mix. Interseeding is done as needed, especially following burning.

Management practices are viewed at this mine as tools to improve the diversity and vigor of the revegetated grasslands. If weeds become a problem, non-selective glyphosate applied in the late spring has been found to improve seasonality. As needed, broadleaf weeds are controlled with 2,4-D and weedy grasses with mowing before they mature in the first year of revegetation. Haying and burning in late spring have also been found to improve seasonality and decrease weeds and are used when appropriate. Grazing of grasslands is allowed once vegetation is established. Selective and carefully controlled grazing has been found to enhance warm-season grass success. Wildlife control is needed in the woodlands, so fences are used to exclud wildlife for the full liability period.

Procedures for cropland and the small area of prime farmland follow standard preparation, planting, cultural, and management practices for the area.

Revegetation monitoring data for grasslands consist of selective sampling of special or problem areas for basal cover, frequency, and production by methods similar to the baseline studies. In woodlands, ground cover and woody plant diversity data are collected as in the premining work, with additional data on growth and survival trends. Data are computerized in-house but summaries are not yet available. Woody draw and grassland demonstration sites have ongoing monitoring to track the success of experimental procedures.

This mine has been involved in research and innovation for over 10 years. It has cooperated with researchers from North Dakota State University and Agricultural Research Service, and has conducted its own trials and experiments. Work has included studies of mulching, grazing, irrigation, seed mixes, topsoil handling and replacement depths, grassland management, and woody draw rehabilitation. Coal company personnel conduct experiments at the grassland and woody draw demonstration sites, as well as at pre-SMCRA sites for which regulatory approval has been granted. Of special recent interest is that better grassland diversity and seasonality have been achieved by newly developed planting, cultural, and management practices.

Lease stipulations require that woodland ecosystems not be destroyed unless unavoidable and unless full rehabilitation can be achieved. Therefore, exclusionary woodlands are left undisturbed and rehabilitation of woody draws has been a high priority. Work by consultants and coal company personnel has shown what factors are important for and what practices will succeed in woody draw rehabilitation. For example, concave sites with north or east exposures are best suited, and species are distributed on parts of the slopes with the most favorable moisture regime.

3.2.4 New Mexico

3.2.4.1 Case Study Mine NM-1. This mine was selected as a full case study because it occurs in a "badlands" area, near the Bisti Badlands wilderness study area, and was urged for inclusion in the report by environmental groups. NM-1 is a relatively new mine and so has only post-SMCRA reclamation.

The mine permit area, located in the San Juan Basin of northwestern New Mexico, has an average elevation of around 5,800 feet and receives only about 7.5 inches of precipitation annually. Premining vegetation of the permit area consisted of Badlands with almost no vegetation cover and of Greasewood/Alkali Sacaton on areas having some soil development and better moisture availability. Both the premining and postmining land uses are native rangeland.

Baseline vegetation data were collected in 1980 and 1981 by mining company personnel and consultants. The sampling design used was not specified in the permit application document. Vegetation was mapped at scales of 1" = 1000' (1:12,000) and a very detailed 1" = 200' (1:2400). Absolute cover by species was determined by occular estimation within 0.1 m^2 quadrats, supplemented by 100 m line intercept transects. Frequency and constancy also were calculated. Production data were collected by clipping herbaceous growth within 0.5 m^2 and 1.0 m^2 plots and reporting the results as kg/ha. Woody plant density was estimated 1 m^2 quadrats and 2 m x 100 m and 3 m x 100 m belt transects, with values reported as stems/hectare. No diversity calcualtions were included in the baseline report.

Revegetation performance standards are to be based on reference areas for cover and production, with the shrub density standard set at 190 stems/acre. A diversity standard has not been established, or at least was not specified in the permit application.

Reclamation methods at NM-1 are interesting, because the badlands "soils" are classified as unsuitable for reclamation. Therefore, a topdressing material must be generated and placed over the badlands materials at a thickness of 18 inches. The present plan calls for mixing the overly fine surface materials with sandy material derived from crushing sandstone strata in the overburden to produce a topdressing having favorable texture and infiltation qualities. The seedbed is to be prepared by discing and contour furrowing to conserve surface runoff.

The revegetation plan specifies seeding in late spring/middle summer (May to July) in order to take advantage of the late summer/early fall precipitation peak. The proposed single seed mix contains four grasses, one forb, and five shrubs at a combined rate of 5.875 PLS lbs/acre (Appendix B). The exact content of the proposed mix hinges on the commercial availability of three desired species: wild buckwheat, black greasewood, and broadscale (Atriplex obovata). Seeds are to be drilled. Nursery stock or on-site transplants of woody plants are not planned at present.

Proposed cultural and management activities include mulching with straw applied at the rate of 0.5-1 ton/acre and crimped in place, and excluding grazing throughout the liability period. Irrigation is not planned, and fertilization is not specifically mentioned in the permit application.

3.2.4.2 Case Study Mine NM-2. The second case study mine in New Mexico also is located in the San Juan Basin, at a somewhat lower elevation than NM-1 (5,000-5,300 feet) and with a lower mean annual precipitation (about 6.6 inches). NM-2, which has both pre-SMCRA and post-SMCRA reclamation, was selected on the basis of its location, aridity, and innovative practices.

Vegetation types, as mapped during baseline studies, include Galleta, Galleta/Fourwing Saltbush, Winterfat/Galleta, Shadscale/Galleta, Shadscale/Alkali Sacaton, Alkali Sacaton/Broadscale, and Greasewood. The primary premining and postmining land uses are (native) rangeland; secondary uses before and after mining are wildlife habitat, oil and gas exploration, and recreation.

Baseline data were collected in 1980 and again in 1983 by mining company personnel and independent consultants. Sample design used random numbers identifying grid cells on a vegetation map at a scale of 1" = 500' (1:6000). Quantitative sampling of cover was by species along 30 m line intercepts; frequency and constancy also were calculated. Production sampling was accomplished by clipping herbaceous and woody plants in 1 m^2 plots, with data expressed as g/m^2 and lbs/acre. Woody plant density was estimated by counting all individuals within 2 m x 30 m belt transects and reporting the data as stems/60 m^2 and stems/acre. Diversity calculations were not included in the permit application.

This mine has been using the historic record approach for establishing revegetation performance standards, but it reportedly is planning to shift to technical standards based on yearly data from nearby areas of native vegetation that are in good to excellent range condition.

Performance standards prior to 1985 were for 3 percent absolute cover, 200 lbs/acre production with at least half of the total usable by livestock, 75 stems/acre shrub density, and a diversity of two grass species with 5-70 percent relative cover each. For 1985 and future revegetation, the performance standards have been raised to 4 percent absolute cover, 250 lbs/acre production (again with at least 50 percent usable to wildlife), 190 woody plant stems/acre, and a diversity of two shrub species with 10-85 percent relative cover each in addition to two grass species with 5-70 percent relative cover each. The tougher standards for 1985 and later reflect the feeling of the State regulatory authority that the earlier standards were too low.

Reclamation methods at NM-2 include direct haul to the extent possible, with topsoil placement at a depth of 8 or 18 inches (depending on premining topsoil thicknesses on differing sites). The seedbed is prepared by discing to reduce clods and contour furrowing to conserve surface runoff.

One seed mix is used, which consists of six grasses and three shrubs at a combined rate of 5.2 PLS lbs/acre. One of the grasses--galleta--has been limited because the State regulatory authority views it as overly aggressive. Neither the mining company reclamation staff nor its consultants are aware of data to support this contention, and such a well-adapted native species is needed in large amounts to ensure successful reclamation. Seeding is in the May-July period because of the late summer precipitation peak in the region. All seed is planted by drilling, and no nursery stock or on-site transplants are used.

Mulch is used only on slopes of 6.5:1 (about 15-16 percent) or more, where 2 tons/acre of native grass hay is crimped into the topsoil. Fertilizers are used sparingly and only when a specific need can be demonstrated. The same approach is taken toward weed control, because the mining company reclamation staff views weeds as having some benefit as a nurse crop or stubble mulch. Wildlife control has not been needed.

The use of irrigation at NM-2 is interesting because monitoring data show that the cover and production drop in the third year, after supplemental watering is withdrawn. This suggests to the mine's reclamation staff that it might be preferable to allow revegetation to develop more slowly under dryland conditions than to artificially produce levels of biomass that cannot be sustained.

3.2.4.3 Case Study Mine NM-3. Located in the Raton Basin of northern New Mexico, this mine benefits from higher mean annual precipitation (16 inches) and higher elevations (7,500-7,800 feet) than the San Juan Basin mines, which is the reason it was selected as a case study.

A total of nineteen vegetation types were mapped for the permit area: Grassy Bottom-main valley; Grassy Bottom--side valley; Grassy Tops-Blue Grama/Arizona Fescue; Grass/Winterfat; Riparian Sedge; Riparian Cottonwood; Pinyon-Juniper; Pinyon-Juniper Grass; Pinyon-Juniper/Oak; Ponderosa Pine; Ponderosa Pine/Oak; Ponderosa Pine/Pinyon-Juniper; Ponderosa Pine/Pinyon-Juniper/Douglas-fir; Ponderosa Pine/Pinyon-Juniper/Grass; Ponderosa Pine/Pinyon-Juniper/Oak; Oak; Mixed Shrub; and Ponderosa Pine/Bunchgrass.

The increased vegetational complexity of this site compared to other mines probably is more apparent than real, because many of the "types" evidently are merely gradational or transitional between other "types." Thus, the mapping of this mine, done at a scale of 1" = 500' (1:6000) by mining company personnel, represents "splitting," in contrast to most mines which for economic and practical reasons tend toward "lumping."

Historic record baseline studies were begun in 1980 by mine staff and summer temporaries using a "subjective" sampling design (i.e., selecting sites felt by them to be representative). Quantitative data were collected as follows: cover--absolute cover by species, with ocular estimation in 0.1 m^2 quadrats for herbaceous species and line intercepts for shrubs, and with relative cover, frequency, and constancy also calculated; production--clipping herbaceous and current year's shrub growth in 0.1 m^2 plots and reporting the results as lbs/acre; woody plant density--total counts within 0.6 m^2 plots (except 375 m^2 plots for types containing ponderosa pine and Douglas-fir, and 2.25 m^2 plots for types containing oak); diversity--not calculated for the permit application.

Performance standards set as of 1985 using the historic record data to date include a shrub density of 436 stems/acre and a diversity value of four grasses and two forbs with 5-70 percent relative cover each and three shrubs with 5-90 percent relative density. Cover and production standards will be set at the end of the historic record period, and a tree density standard also will be added.

Reclamation methods include stockpiling topsoil and replacing it to a depth of 0-18 inches (some sandstone areas to be left bare because of limited topsoil availability and to return the original presence of bare areas). The average replacement depth is 7.2 inches. Seedbed preparation includes discing to eliminate clods and ripping to bind the topdressing to the underlying material.

Three different seed mixes are used: a bottoms mixture containing six grasses, a slopes mixture with thirteen grasses, and a flats mixture with eleven grasses. In addition, the three mixtures contain "trace" quantities of up to eleven forbs, one succulent (a yucca), five shrubs and subshrubs, and a woody vine.

Despite the use of three distinct, and rich, species mixes to improve success on different situations of slope, aspect, elevation, substrate, and moisture, the far simpler postmining than premining vegetation underscores the seeming irrelevance of defining and sampling so many (nineteen) mapping units during the baseline inventory. This is especially true at NM-3 because almost all of the permit area has a premining and postmining land use of wildlife habitat, with only small areas of native rangeland.

Seeding is done from May through July, mostly by drilling but with some broadcasting and with hydroseeding on some very steep or inaccessible areas. Nursery stock is used for woody plants, but results have been poor and this practice may be discontinued. No on-site transplanting has been used thus far.

Cultural practices include native hay mulch crimped or tackified to help keep it in place, and the application of fertilizers (phosphate disced in during seedbed preparation, nitrogen broadcast during the second year as needed). The mine reports that it is prepared to irrigate but that supplemental watering has proven unnecessary to date.

Management activities include chemical herbicides or mowing for weed control and, formerly, the use of "zoom guns" (i.e., noisemakers to frighten big game) for wildlife control. The latter has been discontinued because the animals habituate so readily to the sounds. Grazing will not be allowed until the end of the liability period. This approach is preferred by the mining company because of concern about the effect of livestock on the re-established vegetation, which will be fragile because of relatively steep slopes and thin soils. Revegetation monitoring consists of cover data collection.

3.2.5 Wyoming

3.2.5.1 Case Study Mine WY-1. This mine, which has both pre-SMCRA and post-SMCRA reclamation, was selected for its location in the Powder River Basin and its use of a truck and shovel operation. The permit area lies within an elevational range of about 4,450-4,715 feet and receives an average annual precipitation of 17.2 inches. The amount of natural moisture available is among the highest in the study region.

Baseline vegetation studies conducted in 1979 by consultants included vegetation type mapping of three distinct natural areas--Sagebrush Grassland, Streamside Bottomland, and Drainage Bottomland, plus annual cropland, hayland, and improved pasture--at a scale of 1" = 500' (1:6000). Land uses before and after mining are native rangeland, wildlife habitat, hayland, and improved pasture.

Quantitative sampling was based on random numbers identifying map grid cells. Absolute cover data were collected by species using point intercepts along a 50 m transect; constancy values also were calculated for the cover data. Production was estimated by clipping herbaceous and woody plants in 0.1 m^2 plots and calculating biomass as g/0.1 m^2, g/m^2, and lbs/acre. Woody plant density was based on total counts within 0.1 ha plots. No diversity calculations were made for the permit application document.

Revegetation performance standards originally were to be based on control areas as a means of adjusting the baseline data, but the mine is converting to extended reference areas. Standards set as of 1985 include the baseline data adjusted by control areas for cover and production, the premining woody plant density values (but re-established as dense patches), and a diversity based on percent similarity by lifeform category using a Motyka index.

Reclamation methods consist of direct haul topsoiling to the extent possible and placement to a depth of 19 inches. The seedbed is ripped on the contours at a depth of 18-30 inches and a spacing of 18-40 inches. Seeding is done in the fall or spring, mostly by drilling but occasionally by broadcasting or hydroseeding.

The basic seed mix for most of the site is called the "permanent grazingland" seed mixture. This mix consists of 26.6 PLS lbs/acre of nine grasses, six forbs (including introduced legumes), and one woody plant (winterfat), plus 12 lbs/acre of oats as a nurse crop. However, WY-1 also uses specialized mixes for drainages (five grasses, three forbs), shrub patches (seven shrubs), pastureland (three grasses, three leguminous forbs), and hayland (two forage grasses and/or alfalfa). Nursery stock and on-site transplants have shown some success in experimental use at WY-1 but are not yet applied on a large scale basis.

Culture consists of 2 tons/acre of crimped grass hay mulch or 1 ton/acre hydromulch, fertilization as needed based on soils analyses, and up to 30 lbs/acre of a preparatory crop such as wheat, barley, or rye when conditions are unsuitable for the regular "permanent" mix. Irrigation is not used.

Management practices include mowing or spraying as needed for weed control. Grazing might be begun for vegetation management, but only on areas seeded at least 2 years prior. Wildlife control has not been needed.

Mine WY-1 is notable for its on-site research programs, such as on the effects of nurse crops, mulch, direct haul vs. stored topsoiling, grazing, and the use of sagebrush "potlings."

3.2.5.2 Case Study Mine WY-2. The Powder River Basin is a large area, and this mine was selected in part becasue it represents conditions near the southern limits of the basin. The area is higher (5,400-6,000 feet) and drier (10-14 inches) than the northern part of the basin (e.g., Mines WY-1, MT-1) and, at this mine at least, has acid overburden. The mine has both pre-SMCRA and post-SMCRA reclamation.

The premining and postmining land uses are native rangeland and wildlife habitat. Baseline studies by consultants in 1978 and 1979 identified six vegetation types: Upland Grassland, Upland Eroded Grassland, Prairie Sandreed Grassland, Sagebrush Grassland, Sagebrush Shrubland, and Bottomland Sagebrush. The vegetation map was provided with the permit application at two scales, 1" = 1300' (1:15,600) and 1" = 400' (1:4800).

Sampling was based on random numbers identifying map grid cells and used a two-stage statistical design. Quantitative data were collected as follows: cover--absolute cover by species and lifeform using a ten-point frame, with constancy also reported; production--clipping of herbaceous and woody plants in 0.5 m^2 plots, data reported as g/0.5 m^2 and lbs/acre; woody plant density--both 100 m^2 belt transects and plotless techniques, data presented as stems/ha; diversity--richness (species number) reported for each vegetation type.

Control areas are the basis of adjusting premining values as a performance standard for cover and production. Other performance standards are the unadjusted baseline value for woody plant density, and a diversity based on three cool season grasses with at least 5 percent relative cover each, plus at least 5 percent relative cover for total warm season grasses and for total woody plants.

Reclamation methods involve direct haul topsoiling whenever possible, with placement to a depth of 34 inches over the acid overburden. The seedbed is prepared by deep ripping the spoil and then chiseling on the contour after topsoil replacement. Two seed mixes are used: an "upland" mixture of nine grasses plus big sagebrush at a combined rate of 17.75 PLS lbs/acre, and a "drainage" mixture of five shrubs and two native forbs at a rate of 5.0 PLS lbs/acre. Seeding is in the spring or fall, using a rangeland drill unless steep slopes dictate broadcasting. Two-stage planting is used in the drainage bottomlands with the shrub and forb mixture sown in the spring and the regular grass mixture sown the following fall. No nursery stock or on-site transplants are used for shrubs. However, ponderosa pine and cottonwoods have been planted to a limited extent as large nursery stock, even though they did not occur in the affected area vegetation types.

Cultural and management practices include 10 lbs/acre of Siberian millet planted in spring as a preparatory crop (straw mulch only if the millet fails), fertilizers only if needed based on samples of the reapplied topsoil, and weed control by mowing or spraying only if needed. Irrigation or wildlife control have not been used at WY-2, and grazing is not planned until 2 years before bond release.

Revegetation monitoring data include seedling density initially, and thereafter cover and production. Seedling density is estimated with total counts by lifeform in ten 900 m^2 quadrats per site. The mine also is conducting research on shrub establishment, success of two-pass seeding, interseeding, alternate strip seeding, and different application rates of phosphorous fertilizers.

3.2.5.3 Case Study Mine WY-3. Located in the Green River Basin of southwestern Wyoming, mine WY-3 has an elevational range of 6,500-7,200 feet and a relatively low annual precipitation of 8.5-9 inches. The mine has both pre-SMCRA and post-SMCRA reclamation. Premining and postmining land uses are native rangeland and wildlife habitat.

Vegetation mapping and baseline sampling were based on range sites, named for the characteristic soils, as follows: Sands, Loamy, Shallow

Loamy, Saline Upland, Saline Lowland, Saline Subirrigated, and Impervious Clay. Mapping was done at a scale of 1" = 400' (1:4800).

Baseline data collection, conducted by consultants in 1978 and 1979, was based on a system of random site selection not further detailed in the permit application. Cover data collection was by ocular estimation to the nearest percent in 0.1 m^2 quadrats, with values reported as absolute cover and frequency. Production was sampled by clipping herbaceous and woody growth in 1 m^2 plots, data expressed as lbs/acre. Woody plant density sampling used a plotless method, data expressed as stems/ha. A Shannon-Weaver numerical index was calculated for diversity.

Revegetation performance standards are the baseline values adjusted by control areas for cover and production, the unadjusted premining values for woody plant density, and the baseline Shannon-Weaver index value for diversity.

Reclamation methods include direct haul to the extent possible, and replacement of the shallow soils to a depth of 6 inches (direct hauled) or 10 inches (stockpiled). The seedbed is prepared by ripping on the contour to a depth of 3 feet and then chiseling on the contour.

Seeding is done in the spring or fall, primarily with a rangeland drill. Three seed mixes are used: a Loamy/Shallow Loamy mixture of six grasses, three forbs, and four shrubs at a rate of 21 PLS lbs/acre; a Sands mixture of seven grasses, three forbs, and two shrubs at 19 PLS lbs/acre; and a Saline Upland mixture of five grasses, two forbs, and four shrubs at 15 PLS lbs/acre. All woody plant re-establishment is by seeding.

Cultural and management practices include mulching with 2 tons/acre of hay, crimped into the soil, and occasionally a barley stubble mulch in lieu of hay. Irrigation is not used, nor is fertilization except in cases of obvious need. The revegetated sites are fenced to exclude livestock and feral horses. Weed control is applied as necessary.

Revegetation monitoring data include annual measurements of cover, production, and shrub density, with direct counts of seedling density by lifeform during the first two years. Methods are similar to the baseline procedures, except that shrub density is estimated during monitoring by total counts within 1 m x 50 m belt transects.

Of particular interest at WY-3 is that irrigation was originally stipulated but had to be withheld because the available water source was saline. While the mine has searched for an alternate water source, their revegetation has progressed satisfactorily without irrigation. This led the mine to request relief from the stipulation, which has been granted temporarily. It also should be noted that test applications of the saline water did result in undesirable salt accumulation in the soils.

3.2.5.4 Case Study Mine WY-4. This mine, which has both pre-SMCRA and post-SMCRA reclamation, was selected to represent the Hanna Basin of south-central Wyoming. Like the Green River Basin (e.g., mine WY-3), the Hanna Basin has a combination of high elevation (6,500-7,530 feet) and moderately low precipitation (annual average 10.4 inches). Premining and postmining land uses are native rangeland and wildlife habitat, although the company has reserved the right to manage private surfaces solely for grazing.

Vegetation types delineated and sampled by consultants during the 1981 baseline program consisted of three broad mapping units: Upland Sagebrush-Grass, Bottomland Sagebrush, and Rough Breaks. The vegetation map was prepared at a scale of 1" = 500' (1:6000). Random numbers identifying map grid cells were the basis of the quantitative sampling design.

Absolute cover data were collected by the dubious technique of using marks along a rope as "points." This type of nonrigid placement of oversized "points" effectively negates most of the theoretical advantages of point sampling, such as objectivity and repeatability. Nonetheless, it was accepted by the regulatory authority. Constancy also was calculated from the cover data. Production was sampled by clipping herbaceous vegetation within 1 m^2 plots, with the data reported both as g/m^2 and lbs/acre. Woody plant density estimates were based on 1 m x 50 m belt transects for shrubs and total counts for the scattered conifers; both types of data were expressed as stems/ha. A Shannon-Weaver diversity index was calculated for each vegetation type.

Control areas will be used to adjust baseline data as the revegetation performance standard for cover and production. The standard for woody plant density is the baseline value. The diversity standard is for three cool season grasses with at least 5 percent relative cover, and for total shrubs to contribute another 5 percent relative cover.

Reclamation methods involve some direct haul topsoiling, but most soil is stockpiled because of the mine configuration. Topsoil replacement depths vary from 1" to 23". Some areas are terraced to help control soil erosion and surface runoff. Seeding is in spring or fall, usually by drilling in most cases but with broadcasting in some areas where drilling is difficult.

The basic seed mix at WY-4 includes five grasses and two saltbush species at a total rate of 12 PLS lbs/acre, plus one "experimental" species selected from among ten grasses and one shrub (black greasewood) applied at

1 lb/acre. In addition, bottomlands and north-facing slopes (i.e., more mesic sites) also include a total of 1.25 lbs/acre of big sagebrush, rubber rabbitbrush, and a third shrub species.

Nursery stock of woody plant shas been used on a limited experimental basis, while on-site transplants are used widely, whether by a tree spde, a front end loader, or manually with a shovel. Success has been good to date.

Cultural practices include a certified weed-free native hay mulch, spread at 2 tons/acre and crimped into place, or a stubble mulch of wheat or barley. The annual grains also are sometimes used as a preparatory crop. Fertilizer is used only as indicated by sampling of the respread topsoil, and no irrigation has been used.

Management involves some weed control as necessary, although weeds normally are viewed by this mining company as a type of nurse crop, at least during the first few years after seeding. Grazing is essentially excluded, although some slight use by livestock, especially sheep, does occur. Rabbit predation on shrubs has been a problem in some years, and fencing of transplanted shrub islands has been tried.

Revegetation monitoring data are mostly limited to cover estimates, but some production and shrub density data also have been collected.

The reclamation specialist at this mine has tried a number of innovations on his own initiative. These have included hand collecting woody plant seeds from local stands and hand sowing them in favorable sites such as around rockpiles, planting cottonwoods in favorable sites with a tree spade (this species does not occur in the permit area naturally but would be a welcome addition for wildlife), and annually rotating an "experimental" species into the seed mix.

3.3 PARTIAL CASE STUDIES

3.3.1 Colorado

Three partial case study mines were selected for Colorado. Mine CO-3, a very small surface coal mine in the Raton Basin had reclaimed an area approximately 5 years before this study. Total vegetation cover in the reclaimed area was 56.1 percent in 1984, compared to 50.6 percent (including tree cover) in the corresponding reference area. The reclaimed area was dominated by native species including western wheatgrass, slender wheatgrass, sideoats grama, and Indian ricegrass.

Mine CO-4 is a small surface mine in southwestern Colorado which is mining coal under a surface originally covered by massive sandstone and supporting pinyon pine, juniper, tall shrubs, and scattered patches of primarily warm season grasses in crevices and on small terraces. After coal is removed, the exposed surface will be another massive sandstone stratum. The reclamation plan calls for blasting shelves into this sandstone, placing fine material on these shelves and planting trees, shrubs, and grasses.

Mine CO-5, located in northwestern Colorado, has negotiated a shrub density performance standard based on establishment of mature shrub clumps on 1,300 foot centers. Clumps are established by transplanting mature native shrubs using front loaders or scrapers. Antelope bitterbrush and true mountain mahogany are seeded between the transplanted clumps. Big game predation on young shrub growth in the reclaimed areas is diverted to adjacent undisturbed areas. This is accomplished by crushing the mature, low productivity shrub growth in order to stimulate sprouting of new growth attractive to browsers.

3.3.2 Montana

Mine MT-2, located in the Powder River Basin, is trying a number of innovative practices. The reason the mine was chosen as a case study is that it has one of the oldest programs of ponderosa pine restoration in the study area. Studies by the mine and researchers from Montana State University started in 1978 to determine where the pine naturally had good establishment. The current, successful program includes use of coarse textured, rocky surface soils usually on steep north- to northeast-facing slopes. Containerized nursery stock grown from locally collected seed performs best, but stock from a South Dakota state nursery also performs satisfactorily. Survival of the containerized stock is over 80 percent and sometimes over 90 percent. The most serious threat to success of the pines occurs in the winters when rodents, rabbits, and deer feed upon them. Competition from herbs is controlled by using straw mulch at 1-2 tons per acre. A variance has been granted to delay seeding of ground cover. If volunteer growth is not satisfactory after 3 years, the undergrowth is seeded. Pines planted in 1978 are now 2-3 feet tall. Current densities are about 500 per acre. In order to provide a closed tree canopy for wildlife, MDSL has recently asked the mine to rehabilitate densities of 1,000 per acre, which are not likely to be achieved otherwise for over 30-50 years. The coal company feels that there will be diminishing returns at these densities due to increased competition between the pines. In order to minimize competition, the company plans to interplant in the older rehabilitated pine areas.

3.3.3 North Dakota

At Mine ND-2 Federal lease stipulations require restoration of the wetlands. The NDPSC requires separate handling of clayey wetland soils. The special program of wetland restoration is being carried out by the mining company. Transplants of native vegetation plugs from nearby wetlands have established readily and support good vegetative growth although they are young. Water quality is good and the vegetative growth is typical of class three (seasonally wet) wetlands, including sedges (*Carex* spp.) and smartweed (*Polygonum coccineum*). At a pre-SMCRA lake at another mine held by the same company, vegetative growth has been good from cattails (*Typha* spp.) and three-square (*Scirpus* sp.), although the water is brackish. Success of rehabilitation of the post-SMCRA wetlands is being judged by an advisory panel which the mining company organized and the North Dakota PSC approved. The panel consists of experts on regional groundwater, surface water, fish and wildlife, and aquatic botany representing North Dakota Game and Fish, U.S. Fish and Wildlife Service, North Dakota Mining and Minerals Resources Research Institute, and North Dakota State University. Monitoring includes water quality and quantity, limited groundwater hydrology, and mapping and sampling of vegetation.

3.3.4 Wyoming

At Mine WY-5, the innovative use of annual grains to improve soil organic matter has been investigated. Annual grains have been planted, then plowed into the soil after they have matured. The object has been to enhance soil tilth through the improvements in structure, infiltration, and nutrient holding capacity by increasing the organic matter content. To date, no clear determination of the effectiveness of the practice has been made, except that soil compaction has been relieved.

At Mine WY-6, the need to re-establish approximate original contour and a sage grouse strutting ground has led to the unusual end of committing to reconstruct a playa. The heavy clay soils typical of such features in northeastern Wyoming will be special handled. This will necessitate precise timing to catch the limited range of appropriate moisture content to avoid massive clod or block development and the subsequent difficulty in developing a suitable seedbed. The reconstructed playa will be seeded to western wheatgrass and big bluegrass.

SECTION 4.0

ANALYSIS

4.0 ANALYSIS

4.1 APPLICABILITY OF EXISTING VEGETATION DATA

This section discusses the applicability of existing vegetation data in the mine permitting process and for setting revegetation standards. Sources of existing data include Federal land management agencies, government or university research projects, and mine permit applications already on file at the OSM and various State regulatory authority libraries. The evaluation of applicability is based primarily on the methods employed and parameters addressed by each major source and on methodological differences between them.

4.1.1 Range Management and Basic Research Programs

When range science developed as a branch of plant ecology in the early part of this century, quantitative evaluations of plant cover and production generally consisted of ocular (visual) estimates adjusted by a small number of more objective samples. Throughout the years, government agencies responsible for monitoring range condition and carrying capacity have been the primary collectors and users of range science data (see Section 2.4.1). Quantitative methods employed by these agencies--the SCS, BLM, and USFS--have remained at a level appropriate for management decisions concerning large tracts of land, especially regarding grazing potential. Much of the five state region has been the subject of this type of range evaluation.

Basic research in plant ecology and range science has been conducted by universities and government research agencies in various parts of the five state region. These studies have tended to utilize more comprehensive and sophisticated methods of collecting and analyzing ecosystem data, particularly in the areas of objectivity (repeatability) and statistical reliability. However, the geographic locations of these data sources are not well distributed, emphasizing areas near major universities or their research facilities or sites of some special interest. Furthermore, the quantitative techniques used, although generally more intensive and objective than range management methods, have been developed in relation to diverse research objectives and thus of limited value for comparing or combining with other data.

An example of the few exceptions to this generalization is the detailed monitoring of the Upper Rio Puerco watershed of west-central New Mexico in a cooperative study by BLM and the Rocky Mountain Forest and Range Experiment Station (USFS, see Aldon 1984). Here, fairly intensive data collection using consistent techniques has been undertaken at permanently located sites. Such data eliminate concern about year-to-year variability of data collection techniques and sample locality, allowing evaluation of year-to-year variation in the vegetation parameters and, potentially, the creation of reliable, climate-adjusted technical standards for the particular ecological region.

The advent of requirements for mined land reclamation, especially concerning revegetation performance standards and statistical confidence limits, created a need for vegetation data more objective, repeatable, and reflective of small scale site-specific variability than are currently available from Federal agencies. While research programs typically satisfy these criteria, the areas and years sampled are too limited for use as a regional baseline. Thus, neither source of existing information is sufficient to meet the requirements of the recently developed revegetation performance standards.

This conclusion is supported by the work of Van Dyne and Hollingsworth (1984), who examined the potential use of research data, predictive model data, and SCS data in developing revegetation standards for North Dakota. Their conclusions were that:

(1) research data are of limited utility because of inaccessibility, wide geographic dispersion, lack of consistency in methods, and poor representation over common time periods;

(2) generalized predictions based upon geographic or climatic variables lack sophistication and statistical substance and are not adequately validated;

(3) SCS Technical Guides, which set forth percent species composition "allowable" for theoretical range sites, are not useful because they are neither realistic nor statistically valid; and

(4) SCS year-site data, which are field observations used in establishing the range site values of the Technical Guides, are potentially useful for production estimates if corrected for yearly variations in precipitation and with minor improvements in sampling technique.

In comparison to the type of SCS data analyzed by Van Dyne and Hollingsworth, BLM and USFS data have typically been collected under less rigorously controlled conditions. The variable quality of BLM and USFS data relate to differences in observer skills, and the fact that data are collected from unprotected plots subject to differing intensities of grazing and are usually based on a one-time sampling only. In addition, USFS data cover few areas where surface coal mining is active or planned.

4.1.2 Mine Permit Applications

Vegetation data included in mine permit applications comprise a very large body of information, especially for major mining areas such as the Powder River basin of Wyoming and Montana. Since about 1979, these data have been collected under strict statistical constraints and, to a lesser extent, narrow methodological guidelines established by State or Federal regulatory authorities. Although these data would seem to avoid the shortcomings of the range management and research data bases described above, closer examination casts some doubts on their usefulness, as discussed below.

Production data are collected with reasonably consistent and appropriate techniques (see Section 2.3.2.2), but differences in production data may result depending on whether shrub or annual species production is included. This in turn depends upon the regulations or guidelines of the various states. Errors arise due to the seasonality of the plant species because production usually is estimated based on a one-time sampling, which theoretically coincides with the time of maximum standing crop. In much of the study area, however, the differing times of peak production of the dominant species will cause measured production to be low by an unknown and variable amount (Van Dyne et al. 1984), although these differences probably are overshadowed by the effects of climatic variability.

The accuracy, precision, and comparability of cover data also are open to substantial doubt, even between studies which have used the same general sampling method, because of different levels of observer skill and the wide range of methods employed (see Section 2.3.2.3). Although objectivity and repeatability are theoretically greater in point-sampling than in quadrat sampling, these advantages are substantially reduced by the practice of non-rigid point placement or projection and the use of "points" that are not dimensionless (e.g., see Case Study WY-4, Section 3.2.5.4).

Woody plant density data also are of doubtful comparability, owing to differences in the methods employed and, particularly, species that are counted as shrubs. Direct counts of all woody plants within large quadrats or belt transects provide the most reliable results. Unfortunately, some baseline studies (over 25 percent of approximately 60 mines surveyed) have used very small quadrats or plotless samples, which provide far less reliable data. In any case, the importance of woody plant density data has been diminished by the trend for establishing standards by negotiation between the coal companies and regulatory authorities without reference to precise premining levels.

Vegetation mapping units identified in mine permit baseline studies are diverse, at least in name. It appears, however, that many of the same vegetation types are consistently identified even though the names differ. It has been suggested that the degree of "splitting" of the vegetation into types is not sufficiently detailed in coal mine baseline studies and that a statistical analysis should be undertaken to objectively classify site vegetation as an initial step in the baseline process (Prodgers 1983). While such an approach would more fully explore the plant ecology of a mine permit area, it is doubtful that the additional time and expense would be justified because postmining landscapes are almost inevitably more homogeneous than premining landscapes, typically consisting of a few broad plant communities.

In addition to questions of comparability due to variations in data collection techniques, there is a basic problem with any data not taken at the specific mine site if the data are to form the revegetation performance standards. Regional values of cover, productivity, diversity, or density may be too low or too high compared to the values at the specific mine site.

4.2 APPLICABILITY OF MONITORING AND REVEGETATION RESEARCH DATA

Another objective of the analysis task was to evaluate the applicability of revegetation monitoring data collected at the mines and of revegetation research programs designed to improve overall reclamation success. Revegetation monitoring data, when taken with standard procedures and applied properly, can fulfill the primary goal of identifying revegetation problems at individual mines before they become critical. Present variability in methods of data collection, analysis, and presentation somewhat limits their value for broader use. Nonetheless, revegetation monitoring data of various methods of collection from every mine would be preferable to the present absence of any substantive quantitative data in the public domain for most mines.

Revegetation research and experimentation produce data applicable to specific problems at particular sites, and they have fulfilled the goal of improving revegetation results at least over the short term. The substantial advances in revegetation technology that have resulted from research during the last 10 years have greatly increased the likelihood of achieving revegetation performance standards throughout the study area (see Section 2.9).

4.3 EFFECTIVENESS OF CURRENT METHODS FOR SETTING REVEGETATION PERFORMANCE STANDARDS .

The following subsections briefly discuss the effectiveness and limitations of the various methods currently used for setting revegetation performance standards and for adjusting the standards to changes in environmental conditions over time. See Sections 2.7 and 2.8 for descriptions of the performance standards and the systems of evaluating revegetation success.

4.3.1 Cover and Production

Yearly differences in vegetation cover and production as a function of weather patterns are a well known fact to ranchers and plant ecologists in the western United States. The unadjusted baseline data and technical standards systems are limited in their effectiveness because they do not adjust for this type of environmental change, and thus may result in standards either higher or lower than appropriate for conditions at the time revegetation success is evaluated. Using existing data from government agencies as technical standards is of limited practicality, because (1) diversity and shrub density data are seldom included; (2) cover data either are not included or are based on unacceptably small sample sizes and nonrepeatable methods; and (3) production data have been collected from unrepresentative sites.

Despite their shortcomings, the use of technical standards can be advantageous in that it eliminates the need for costly baseline studies and provides a more valid goal in situations where premining vegetation has been depleted, such as from overgrazing.

In contrast, the other revegetation performance standard systems--control areas, reference areas, and historic record data--were designed specifically to account for long-term environmental change. Control areas or reference areas are easier to establish than an historic record, but fluctuations within these relatively small (2-3 acre) plots do not necessarily exactly parallel average fluctuations in the much more extensive affected area. This is because vegetation exists as a mosaic resulting from minor differences in the physical environment, localized population cycles of small animals, the natural growth and senescence of individual plants and plant populations, and the cumulative effects of differences in land use.

Another problem with the use of control areas and reference areas is that they may have to be relocated because of changes in a mine plan, or, worse yet, may be damaged or eliminated by actions of third parties, e.g., during oil exploration drilling that sometimes proceeds outside the control of mine personnel. When necessary to move a reference or control area, calculations of statistical comparability for each successive replacement area introduce compounded imprecisions that eventually may lead to a revegetation performance level mathematically acceptable but actually considerably lower than the standard originally set.

The historic record approach directly assesses the degree of vegetational change through time at a particular site prior to setting a revegetation standard and thus avoids the problem of reliance on data from a single year or from unrepresentatively small control areas or reference areas. However, this system has two major drawbacks: first, collection of baseline data over several consecutive years is expensive, especially if a statistically adequate number of samples is taken each year, as New Mexico MMD apparently requires; and second, the system (as presently applied) uses the arithmetic mean of the sampling period as the revegetation standard, with no attempt to adjust for climatic conditions at the time revegetation success is tested. This second problem essentially negates the advantage of basing a standard on a full "climatic cycle."

New Mexico, the only state in which the historic record approach has been widely applied, has most recently turned toward use of technical standards, since much of the coal mining area of northwestern New Mexico has experienced prolonged overgrazing by livestock which has severely depleted the vegetation. Concern has been expressed by OSM and State authorities that this situation amounts to improper management (30 CFR 816.133), and that postmining land use standards should be based on properly managed areas nearby rather than on improperly managed areas. Properly managed lands are difficult to locate in northwestern New Mexico, especially ones that are adjacent to a particular mine. There is a growing consensus among regulatory personnel that data from overgrazed mine areas result in unacceptably low performance standards. Consequently, New Mexico has begun to negotiate technical standards for mines based on SCS or other data originating from sites in better (higher) ecological condition.

4.3.2 Woody Plant Density

The woody plant density performance standard was originally tied to premining density. In Wyoming, Colorado, and New Mexico, this approach has been found to have two major shortcomings. First, even with the most advanced shrub establishment technology, there is no field evidence that extremely high densities can be re-established during the 10-year liability period. Second, high densities detract from the premining and postmining land uses of grazing and, in some cases, wildlife habitat.

On many sites, overgrazing has decreased the vigor of the herbaceous cover and allowed woody species to invade and attain undesirably high densities. The overabundance of woody plants on western rangeland has long been a source of aggravation and economic distress to ranchers, even though their grazing practices are often partly to blame. Many ranchers, frequently with financial or physical support from the government, have undertaken large scale programs to remove woody species from rangelands.

Some wildlife species undoubtedly have benefited from the expansion of woody cover resulting from overgrazing, while others have suffered. In any case, many State regulatory and mining industry personnel feel that lower woody plant densities, especially if accomplished as groupings, provide wildlife habitat as valuable overall as high premining levels. Consequently, lower woody plant density values may be negotiated by the regulatory authorities in Wyoming, Colorado, and New Mexico. In North Dakota, woody plant density standards have been developed only for woody draws because of the paucity of shrubs or trees in upland sites. At one mine where woody draws are being disturbed (case study ND-1), the density performance standard has been set at three different levels for the three vegetation types present in the draws: short shrubland, tall shrubland, and mixed deciduous woodland. About a third of the woodland plantings are required to be trees.

Wyoming is the only state so far to begin the procedure to formally adopt a woody plant density standard, which is part of a group of proposed revisions to Wyoming regulations under review by OSM. The Wyoming proposal states that 10 percent of the reclaimed surface of areas where wildlife habitat is the postmining land use should have shrub densities of at least one stem per square meter (4,050 stems per acre). This has been welcomed by most mine operators interviewed, because it generally lowers the standard from premining levels to a level potentially achievable by planting shrubs in the areas most suitable for their establishment and survival. If premining density values are lower, then the lower baseline figure will be used as the standard. The remaining 90 percent of the affected area of shrubland types should have shrubs included in the seed mix, but there are no density performance standards that must be met. The rationale for the lack of a standard for the remaining 90 percent of the area is that the dense shrub "patches" will effectively re-establish the desired wildlife habitat values.

OSM apparently has not set a formal policy on the acceptability of woody plant density standards below premining values, but several Colorado and New Mexico permits with reduced standards have passed OSM review successfully.

4.3.3 Diversity

Two indices of diversity that have been most commonly used on western mined lands are the Shannon-Weaver (also known as Shannon-Wiener) diversity index (H') and the Motyka (also known as Bray and Curtis) similarity index. Both require a species or lifeform list and a measure of importance per species or lifeform (such as cover or production) within each area, and both utilize richness and evenness information to obtain the index. The Shannon-Weaver index produces a value for one area that is not intuitively comparable to a value from another area, whereas the Motyka similarity index produces a measure derived from direct comparison of species in common between two areas (e.g., revegetated areas and reference areas). Figures 11 and 12 show sample calculations of these indices.

Before 1981, OSM was a strong proponent of the Shannon-Weaver index of diversity (Bonham et al. 1981). This numerical value has been used widely in academic studies, but its use in an applied situation is of concern to some regulators and mining industry personnel because it does not consistently compare the apportionment of species abundance in two areas such as revegetated and reference areas (Chambers 1983). One problem involves situations where simply comparing Shannon-Weaver indices could result in approval of revegetation that meets the mathematical goal but consists of inferior species composition. For example, a reference or control area with species A, B, C, and D apportioned with a relative abundance of 10, 2, 2, and 1 would have the same H' value as a revegetated area with species A, B, C, and D apportioned at 1, 2, 2, and 10, or even with four totally different species, E, F, G, and H (example modified from Chambers and Brown 1983) (see Figure 11). Conversely, ecologically advantageous revegetation could be disapproved because of some mathematical discrepancy.

In the search for an objective but more intuitive diversity performance standard, the Motyka similarity index has been tried. Similarity indices are better suited for comparisons between revegetated and reference or control areas because they address the number of species common to the two compared areas as well as the richness and can be used to address apportionment of species within each (see Figure 12). Thus, two areas which are compositionally distinct cannot have a high similarity index, even though they might have identical numerical diversity indices as illustrated in the

Figure 11

Example of a calculation of the Shannon Index (from Chambers and Brown 1983)

The formula for an infinite population is

$$H' = -\sum_{i=1}^{s} p_i \log p_i$$

where p_i is the percentage importance. The index, H', is logarithmically related to the number of species.

	Revegetated Area			Reference Area		
Lifeform or species	lb/acre DW	p_i	$-(p_i \log p_i)$	lb/acre DW	p_i	$-(p_i \log p_i)$
1	553	0.200	0.140	524	0.177	0.133
2	479	0.173	0.132	348	0.117	0.109
3	234	0.084	0.090	441	0.149	0.123
4	625	0.226	0.146	563	0.190	0.137
5	351	0.127	0.114	197	0.066	0.078
6	26	0.009	0.018	151	0.051	0.066
7	108	0.039	0.055	94	0.032	0.048
8	84	0.030	0.046	175	0.059	0.073
9	67	0.025	0.039			
10	242	0.087	0.091			
11				269	0.091	0.095
12				43	0.014	0.026
13				123	0.042	0.058
14				36	0.012	0.023
Σ	2,769	1.000	0.872	2,964	1.000	0.969

Figure 12

Example of a calculation of the Motyka Index (from Chambers and Brown 1983)

This example shows a moderately high degree of similarity between the two areas.

Motyka's version of Sorensen's similarity index (IS_{MO}) is:

$$IS_{MO} = \frac{2\ MW}{MA + MB}$$

where MW = sum of the smaller importance values of the species or lifeforms common to both areas

MA = the sum of the importance values of all species or lifeforms in one area

MB = the sum of the importance values of all species or lifeforms in the other area

The value of the index ranges from 0 to 1, with 1 being complete similarity.

	Revegetated Area (MA) lb/acre DW	Common Species		Reference Area (MB) lb/acre DW
Species		(MA) lb/acre DW	(MB) lb/acre DW	
1		553	524	
2		479	348	
3		234	441	
4		625	563	
5		351	197	
6		26	151	
7		108	94	
8		84	175	
9	67			
10	242			
11				269
12				43
13				123
14				36
Total	309			471

Figure 12 (con't)

Calculation of Motyka and others' version of Sorensen's index.

$$IS_{MO} = \frac{2\ MW}{MA + MB}$$

MW = 524 + 348 + 234 + 563 + 197 + 26 + 94 + 84 = 2,070

MA = 553 + 479 + 234 + 625 + 351 + 26 + 108 + 84 + 67 + 242 = 2,769

MB = 524 + 348 + 441 + 563 + 197 + 151 + 94 + 175 + 269 + 43 + 123 + 36
= 2,964

$$IS_{MO} = \frac{2(2{,}070)}{2{,}769 + 2{,}964} = 0.72 \times 100 = 72\%$$

preceding paragraph. Nonetheless, questions remain concerning the level of similarity (usually calculated on a lifeform basis) that should be required. Also, it may be possible for a revegetated area to have greater diversity than its reference area while showing an unacceptably low index of similarity.

Because of the lack of agreement on a theoretically-based standard, there has been a tendency for agencies to not establish diversity standards until practically based methods and levels can be developed. As a result, standards generally have been negotiated on a case by case basis. A fairly large number of mines have adopted a lifeform/relative cover approach, in which a commitment is made to returning a certain number of species in specified lifeform categories. These species typically must comprise at least some minimum proportion (ranging from 1 to 5 percent) but less than some maximum proportion (often 70-80 percent) of the total vegetation cover. Abundance limits for the shrub lifeform are sometimes set by relative stem density rather than relative cover. This lifeform/relative cover method is commonly used in New Mexico and Colorado, while the Motyka similarity index is prevalent in Wyoming. Montna uses weighted values of diversity (see Section 2.7), although MDSL is reviewing their requirements.

Mines with a numerical diversity index or similarity index standard are subject to the greatest uncertainty concerning success. Mines that have negotiated a standard based on the number of species within particular lifeforms and above specified levels of abundance generally are more confident that they can meet the standard because it is a concrete goal that can be directly sought. In contrast, a mathematical index is much less intuitive and less amenable to direct planning.

4.4 ACHIEVEMENT OF PERFORMANCE STANDARDS UNDER SMCRA

As discussed previously, final evaluation of western surface coal mine revegetation under provisions of SMCRA has not yet occurred because the 10-year liability period is still in effect at even the oldest revegetated areas. Consequently, objective assessment of success must be based on interim or monitoring data collected by the individual mines or, in some cases, regulatory personnel. While some State regulatory agencies require information on the progress of revegetation as part of an annual report, most mines merely state the extent of revegetation that year and whether it is successful. Few mines have routinely collected and interpreted detailed monitoring data or reported it in an organized, informative way. Thus, the following conclusions are necessarily based upon incomplete information. The companies conscientious enough to collect, analyze, and submit monitoring data reports are possibly those also doing the best reclamation work.

4.4.1 Cover and Production

In the early revegetation efforts at western surface coal mines, the use of a few introduced wheatgrasses generally resulted in cover and production that easily exceeded the native vegetation in the comparison areas. However, the long-term stability of this introduced, low-diversity vegetation, and its usefulness for wildlife and livestock, are debatable. With the increased concern for diversity, native species, and woody plants, the highly productive and aggressive introduced grasses were largely phased out of seed mixes. Consequently, cover and production now develop somewhat more slowly during the revegetation process, but results have generally been good thus far.

An exception is northwestern Colorado (case study mine CO-1), where conditions for revegetation are more favorable than anywhere else in the five-state study region and significant amounts of introduced species continue to be used in the seed mixes. There, the development of cover and production has been very rapid. For example, seedings 3-7 years old have about 60-85 percent cover compared to baseline levels of 43-82 percent cover, while herbaceous production levels in reseeded areas are about 750-1,000 g/m^2 (6,600-8,900 lb/acre) compared to 100-340 g/m^2 (890-3,000 lb/acre) in baseline vegetation types. In a trial at the same mine, unseeded direct haul topsoil supports about 75 percent cover and about 240 gm^2 (2,140 lb/acre) herbaceous production after just 4 years.

Mines farther west in Colorado have somewhat less annual precipitation and baseline levels of cover and production. Nonetheless, examination of limited monitoring data from this area indicates that, for both parameters, baseline values are closely approached within 2 years and exceeded by 5 years.

In the Powder River Basin of Wyoming and Montana, growing conditions are somewhat less favorable than in northwestern Colorado. Data collected by mine personnel indicate that cover and production on revegetated sites are meeting or exceeding premining levels when native seed mixes are used. The same conclusions were expressed by mine personnel in the Ft. Union region of Montana and North Dakota.

At the opposite end of the spectrum within the five-state study region are southwestern Wyoming and northwestern New Mexico. In southwestern

Wyoming, where annual precipitation is less than 10 inches, monitoring data from case study mine WY-3 show that, within 2-3 years after seeding, foliar cover ranges from 16 to 30 percent compared with 10 to 30 percent for various premining vegetation types in the affected area. Production in revegetated areas in 1984 was 13-40 g/m^2 (116 to 357 lb/acre) compared to 21-78 g/m^2 (187 to 696 lb/acre) within the various vegetation types of the affected area. The baseline production figures include shrubs, while the revegetated area production data include only herbaceous species. Thus, while the data are not directly comparable, achievement of similar levels of herbaceous production is indicated.

Cover and production in arid landscapes such as southwestern Wyoming are strongly affected by precipitation. Data for 1983 at case study mine WY-3 showed higher cover and production than for 1984. The year 1983 had above normal precipitation, while 1984 was somewhat below average through the growing season, as was the baseline year of 1979. Thus, the comparison of 1984 monitoring data to the 1979 baseline data fairly accurately reflects the progress of revegetation at case study mine WY-3. Although irrigation was at one time thought necessary at this mine, it was never implemented due to water supply problems. Existing revegetation has been accomplished without irrigation.

Irrigation is used for the first 2 years at case study mine NM-2 in northwestern New Mexico. Here, cover in 1984 was from 4 to 5 percent on revegetated areas 3-6 years old, while cover in concurrently sampled native stands was 1-5 percent. Production in 1984 was from 24 to 48 g/m^2 (215-430 lb/acre) on areas 3-6 years old, compared to native stand production of from 12 to 50 g/m^2 (110-450 lb/acre).

Particularly interesting at NM-2 is the fact that cover values observed in 1984 were down from the previous year by factors of 70-80 percent, while production was down by 50-55 percent. The reason for this decline has not been determined, but it was matched by a decline in native stands where cover fell by 55-75 percent among the seven vegetation types being monitored. Changes in production from 1983 to 1984 for the seven native vegetation types ranged from a 48 percent decline to a 12 percent increase. These data suggest that variations in cover and production between revegetated areas are consistent, and that the revegetated areas vary in a manner substantially paralleled by similar native stands. These types of detailed data, collected yearly from revegetated and native undisturbed areas, are extremely valuable for investigating such issues as permanence and long-term stability and illustrate the importance of monitoring data.

It is worth noting that in conversations with personnel at over twenty mines throughout the study area, none was pessimistic regarding the prospect of achieving cover or production standards.

4.4.2 Woody Plant Density

Achieving woody plant density performance standards has been a concern throughout the study region, and the technology of shrub re-establishment has received much attention. One area of particular concern for shrub and tree establishment is in the coal regions of Colorado and Wyoming, where woody vegetation is extremely important to big game. Monitoring data for case study mine CO-1 in northwestern Colorado, in an area dominated by mountain shrub vegetation, show a range of shrub density from 0.28 to 0.86 stems/m^2 on 3 year old seedings and as high as 1.02 stems/m^2 on 1 year old seedings. The shrub density standard in this case is 0.25 stems/m^2. These results are from a mine (case study CO-1) that has attempted many innovative practices with positive results.

Monitoring data available from mines in slightly less favorable environments indicate that earlier shrub establishment technologies have resulted in generally lower shrub densities in the range of 0.05 to 0.15 stems per acre. Most Colorado mines have at least experimented with the types of techniques for reducing competition that have proven successful at CO-1 and reportedly have had encouraging results.

Fewer data are available concerning shrub establishment in sagebrush steppe ecosystems in the northern part of the study area. In general, it has been difficult to establish shrubs other than fourwing saltbush in the Powder River Basin of Wyoming, with big sagebrush being especially difficult. The prospects of meeting proposed shrub density standards of one stem per square meter on 10 percent of the area may depend upon whether fringed sage (Artemisia frigida) and Gardner saltbush (Atriplex gardneri) are counted as shrubs for density purposes. On many sites, these small species are successfully established from seed or as volunteers. In southwestern Wyoming, big sagebrush establishment has proven more successful. Monitoring and other revegetation data available suggest that shrub densities of one stem per square meter can be realized within the early part of the liability period using direct seeding and one of the various methods for reducing competition. Planting of nursery stock usually is too expensive and results too poor for large-scale use, but cost effectiveness may be improved with technologies being developed at case study mine WY-1. Likewise, onsite transplants of mature shrubs are of limited feasibility for meeting density standards because of cost. However, shrub islands established from onsite transplants may prove valuable as seed sources for volunteering shrubs later in the liability period.

At case study mine NM-2 in New Mexico, 1984 shrub density values in revegetated areas 3-7 years old varied from 0.03 to 0.3 stems per square meter. The shrub density standard at this particular mine is 0.019 stems per square meter. In Montana (MT-2), ponderosa pine is being successfully established at densities of approximately 500 stems per acre using local nursery stock. Nursery stock also has been used for plantings of deciduous trees and shrubs at densities of 2,700 stems per acre along recreated woody draws in North Dakota (ND-1). Progress toward meeting the performance standards at these mines has been good.

4.4.3 Lifeform and Species Diversity

Achievement of lifeform and species diversity has been the subject of concern by regulators and industry for several years. However, recent advances in revegetation technology have begun to show positive results.

At Wyoming case study mine WY-2, the lifeform and species diversity standard is for three cool season grasses with at least 5 percent relative cover, warm season grasses totaling at least 5 percent relative cover, and shrubs totaling at least 5 percent relative cover. Based on 1983 data, revegetated areas from 2-3 years old had two cool season grasses over 5 percent relative cover, although neither warm season grasses nor shrubs were yet over 1 percent relative cover.

At Wyoming case study mine WY-3, the lifeform and species diversity standard is unspecified. Data for 1984 from areas 2-4 years old showed that three to seven species (not including annual weeds) had relative cover values of 5 percent or more. This usually included one or two shrubs; the remainder were native cool season grass species. This compares favorably with the diversity of four to seven species with over 5 percent relative cover in the major upland vegetation types as reflected in baseline data.

In Colorado at case study mine CO-2, the diversity standard is for four species to have 3-40 percent relative cover. Data from 1984 for an area seeded in 1981 showed ten species with 3-40 percent relative cover, while 1984 data for an area seeded in 1979 showed eight species in the required range.

At case study mine NM-2 in New Mexico, the species diversity standard for areas seeded before 1984 is two grass species with 5-70 percent relative cover each. Areas seeded after 1984 must have those two grass species plus two shrubs with 10-85 percent relative shrub density. Data from 1984 for seedings 3-7 years old showed one or two grasses in the appropriate relative cover range and no or sometimes one shrub. As noted above in the discussion of cover and production at this mine, conditions in 1984 apparently were dramatically less favorable than in 1983 both for revegetated areas and native vegetation. By comparison, in 1983 there often were as many as three non-weedy grass species with 5-70 percent relative cover. Only one shrub species typically occurred with the specified relative cover values.

4.5 TEST GRAZING

Grazing of revegetated native rangeland and tame pastureland are addressed separately in this report from other performance standards for vegetation because grazing involves land use questions as much as vegetation parameters. Little attention has yet been paid to grazing of revegetated land in most of the study area. It is likely that grazing questions will become an issue as more revegetated grazinglands approach the end of the liability period, particularly in four states (Colorado, Montana, New Mexico, and Wyoming) where test grazing is required. In fact, since native rangeland is the predominant land use on mined lands in the study area, the long-term restoration of grazing capacity is one basic question underlying many of the other vegetation issues addressed in this report. Hopefully, evaluation of the response of revegetated areas to grazing will provide data needed to resolve this question.

Revegetation success and the restoration of grazing capacity on tame pastureland are attainable if proper procedures are used (Doll et al. 1984, Reis and Hofman 1984). Therefore, the following discussion focuses on native rangeland, although most of it also applies to tame pastureland.

4.5.1 Livestock Use and Response to Grazing

Livestock use of an area generally is described with reference to the animals, vegetation, and management practice involved. Aspects of the animals grazed include the species (sheep, cattle, horse), sex-age class (yearling, steer, cow-calf, etc.), and total number. Vegetation factors are the type of forage provided (e.g., shortgrass or midgrass prairie vs. tame pasture) and initial range condition, the latter being based upon the existing productivity by species compared to climax conditions. Management activities include the system of grazing, such as rest-rotation, deferred rotation, or best pasture, and the season and length of time when the animals are on the land.

All of these aspects of grazing use are important for understanding a particular situation because they ultimately relate to the long-term impacts of livestock on the quality and quantity of rangeland or pastureland forage. These long-term responses may be assessed by measuring a number of parameters related to the livestock, the vegetation, and other site features.

The condition and performance of the grazing animals, as indicated by weight gain, overall health, and reproductive success, is closely tied to the quality and quantity of forage. Thus, as range condition gradually decreases due to excessive use, so too does the quality and quantity of livestock supported. Readily quantifiable shifts in vegetation composition (i.e., relative abundance or dominance of the various species), cover, production, and percent utilization are the most direct methods of documenting long-term effects of grazing on vegetation. Perhaps less obvious but of great long-term significance are the effects of overuse on soils, such as increased soil erosion due to loss of cover and compaction from heavy use of a small area. Some responses may be tested by simulated grazing, such as clipping studies that imitate the harvesting of the vegetation by livestock.

Assessing these response parameters can demonstrate whether present grazing use will maintain the livestock and the grazingland in a desirable state that can be continued indefinitely.

4.5.2 Test Grazing Data

The Agricultural Research Group at the Northern Great Plains Research Center in Mandan, North Dakota, formerly conducted an active research program on plant, animal, and soil responses to grazing on reclaimed tame pasturelands (e.g., Hoffmann et al. 1981, Hofmann et al. 1983, Ries and Hofmann 1984). The Montana State University Reclamation Research Unit also carried out grazing work on pre-SMCRA reclaimed tame pastureland (DePuit et al. 1977).

Range management data have been collected throughout the study area by Federal agencies for many years (see Sections 2.4.1 and 4.1.1). In comparison, data from mined lands are limited and data for native rangelands are only a small subset of these data. Also, test grazing of reclaimed native rangelands has been done only recently.

The USFS Southwestern Region is cooperating with New Mexico State University on a simulated grazing study at one mine in New Mexico. Initial results are currently being analyzed and prepared for publication. Test grazing has been carried out at case study mine CO-1 in Colorado and ND-1 in North Dakota. Results of preliminary studies at ND-1 (which started in 1979) indicate good animal and vegetation response. Except for small scale tests at case study mine WY-1, Wyoming DEQ was not aware of any test grazing in its jurisdiction. Four Montana mines are presently carrying out test grazing, including case studies MT-1 and MT-2. These Montana mining companies usually start light grazing as soon as the vegetation is well established and they receive approval from the regulatory authority. This light grazing is viewed as a beneficial tool in managing the re-established rangeland and allowing early detection of potential problems such as erosion. The positive attitude toward test grazing in Montana probably stems from the combination of a relatively short time to re-establish vegetation (typically only 3-4 years) and the strong predominance of livestock grazing as the postmining land use. Other parts of the study area may have either slower revegetation (e.g., New Mexico and much of Wyoming) or less emphasis on native rangeland (i.e., North Dakota).

4.5.3 Regulation of Test Grazing

The regulation of grazing on reclaimed mined lands is different in each of the five states (Table 7). The Wyoming DEQ hopes to obtain voluntary cooperation in the submission of plans for the two years of required test grazing and for monitoring data on vegetational responses. North Dakota, while not requiring test grazing, does require submission of grazing plans if there is to be test grazing and joint agreement by the PSC, the landowner, and the coal company as to when the grazing can start and at what intensity (i.e., stocking).

Colorado, Montana, and New Mexico require two years of test grazing and prior submission of grazing plans, but Montana's requirements are most rigorous because they specify that the plan address in detail the species, grazing system, and data collection procedures. Montana also requires test grazing of the reference area along with the revegetated area. In the other four states, the perspective of the regulatory authorities is that they have not yet needed to give much consideration to test grazing.

4.5.4 Summary

There has as yet been little test grazing of revegetated native rangelands in most of the study area. Attention needs to be given soon to what should or should not be required concerning: (1) specificity of grazing plans, in terms of emulating the premine or postmine grazing situation, e.g., types of animals, season of use, system of grazing; (2) specificity of

TABLE 7

STATE REQUIREMENTS CONCERNING TEST GRAZING

	CO	MT	NM	ND	WY
Submission of grazing plan required	yes prior to grazing	yes in permit application detailed	yes prior to grazing	yes in permit application	no
Grazing required at end of liability period	2 years	2 years	2 years	no	2 years

data collection in terms of responses to grazing by the animals, vegetation, or soils; (3) interpretation of different levels of response to the grazing situations, i.e., which levels are acceptable; and (4) specificity and timing of data submission to the regulatory authority.

Existing data and regulatory processes may satisfy some of the test grazing needs. For example, grazing studies by Hofmann et al. (1981) on reclaimed lands showed that live foliar cover plus litter adequately predicts protection of soil from erosion. SCS guidelines could be utilized to address the acceptability of different levels of vegetation and soil response. On the other hand, current requirements for submission of monitoring data prior to Phase III bond release will not improve the availability of test grazing data.

5.0 ISSUES ANALYSIS

This section of the report presents and discusses some of the important revegetation issues that became evident during the course of the study. The study involved an overview of the status of revegetation at surface coal mines in the study area and therefore these analyses focus on identifying problems and questions rather than providing solutions and answers. In general, the issues may be categorized as falling into two broad categories: those that relate to regulatory objectives, such as the use of shrubs and the achievement of lifeform and species diversity, and those that relate to the regulatory process, such as the collection and use of monitoring data and the effect of the regulatory framework on innovation.

The distinction between these two broad categories is not always clearcut, however, and some issues such as the evaluation of revegetation permanence are both goal- and process-related. The general arrangement of the following subsections is with the more goal-oriented issues presented first.

5.1 USE OF NATIVE VERSUS INTRODUCED SPECIES

One of the issues in revegetation of western surface coal mines has arisen from specific requirements for the use of native species, at least where (as in most cases) the postmining land use is to be native rangeland and wildlife habitat. Native vegetation is clearly the preferred postmining cover for these land uses under the provisions of SMCRA, with introduced plant species allowed only when desirable for erosion control or necessary to achieve the approved postmining land use, as long as they are neither "noxious" nor poisonous. The general direction of regulatory restrictions on the use of introduced species for native rangeland and wildlife habitat has been to further restrict their use to situations where they represent a small enough portion of the seed mix that they are not likely to become dominant.

Even if the use of introduced species for native rangeland and wildlife habitat were not restricted by law, their aggressive nature would argue against their use in most cases in order to encourage less aggressive species and, thus, to facilitate the achievement of required diversity and shrub density levels. Another problem with introduced species is that their long-term stability without continued intensive management cannot be assumed. While a few introduced grass species may persist for over 30 years (Valentine 1980), others decline rapidly after a few years and cannot prudently be considered as desirable large components of the species mix.

To some mine personnel, however, it seems wasteful and inefficient to return native plant cover when introduced species could be established more easily and inexpensively and, in some situations, support more livestock. However, controversy over the use of introduced species to support livestock centers in large part on the definition and appropriateness of the "pastureland" versus "native rangeland" grazing uses, which is an issue beyond the scope of this study.

Two general categories of introduced species continue to be used--some aggressive introduced grass species that are valuable for quickly stabilizing soils and certain introduced legumes (i.e., members of the "bean" or "pea" family) that improve soil fertility by "fixing" nitrogen into a utilizable form. Native legume seed sources are not yet widely available, sometimes making it advantageous to use such introduced species.

The persistence and apparent success of some introduced species, such as crested wheatgrass, illustrates the contention of some researchers that the concept of adapted versus unadapted species is more appropriate than native versus introduced species (Monsen and Plummer 1978, Thornburgh 1982). Proponents of either concept agree that native plants have survived and dominated the site because they are adapted for long-term viability on the particular soils and under the particular extremes of temperature, moisture, wind, growing season, and land use of the site. They also would agree that introduced species which perform well on disturbed lands can survive a wide range of soil and climatic conditions, including good performance on the homogenized postmining soils which are never an exact replication of the premining soil environment to which the natives are adapted. However, these researchers would argue that persistent introduced species are as "well adapted" as natives.

In our view, while adaptation is a key consideration it does not address all the biological complexities of the situation. The requirement for permanently supporting a postmining land use of native rangeland or wildlife habitat demands that vegetation diversity be restored, which can be problematical without the cautious use of introduced species. The importance of such diversity is discussed further in Section 5.3.

5.2 USE OF SHRUBS

Another major issue in revegetation of western coal mines is the requirement to establish shrubs. The following subsections describe problems with the use of woody plants in rangeland and their value to wildlife.

5.2.1 Conflict with Grazing Use and Range Improvement Programs

For the most part, ranchers would prefer that postmining landscapes have fewer woody plants than before, at least concerning the sagebrush steppe, mountain shrub, and pinyon-juniper ecosystems that dominate much of the coal-mining lands in the study region. The reason for this attitude is simple: cattle, and to a lesser extent sheep, prefer herbaceous vegetation to shrubs. Cattle are heavily oriented toward grazing, although they do consume current year's growth on smaller shrubs (and especially subshrubs) during fall and spring. Sheep also are primarily grazers, but they tend to prefer forbs rather than grasses and to make greater use of shrubs than do cattle. This enables them to forage successfully (along with goats) in herb-poor desert shrublands in the Southwest and to be kept on rangeland throughout the winter even at northern latitudes. The use by livestock of shrubs during the winter derives from the fact that they are more nutritious than the above-ground portions of dormant herbaceous species and more available because they protrude above the snow cover. Even so, the quality of sheep range, like that of cattle range, is more apt to be limited by the abundance of palatable herbaceous species than by shrubs.

The attitude of ranchers is further reflected by the fact that the major rangeland management agency in the study region--the BLM--conducts or encourages "range improvement" programs designed to increase the availability of forage for livestock. A substantial element of these programs has been the thinning or killing of woody plants, especially big sagebrush, Gambel's oak, pinyon pine, and juniper. This has been accomplished by chemical means (spraying with a broadleaf herbicide), mechanical means (root-plowing or chaining), or burning.

These programs also can benefit big game herbivores if done correctly and in the right areas. For example, thinning big sagebrush to increase herbaceous production can improve the forage for pronghorn as long as shrubs remain available on winter range and are not totally removed from summer range. Similarly, thinning of dense oakbrush can greatly improve the forage value for elk by increasing herbaceous production and for deer by stimulating the growth of young shoots that are more nutritious, palatable, and easily reached. For both deer and elk, however, thinning must be done in relatively small blocks so that adequate densities of tall brush and trees remain nearby for cover.

The issue of postmining versus premining shrub densities is further complicated by the widespread belief that present shrub densities are generally greater than "natural" levels because of historic grazing pressure. Thus, range managers and ranchers often feel that mine reclamation programs should de-emphasize shrubs, because high densities decrease the value of the land for livestock and are not "natural" for the region. While it is true that very high densities of shrubs such as sagebrush and Gambel's oak may result from overgrazing (i.e., selective removal of the forbs and grasses with which shrub seedlings must compete for moisture, nutrients, light, and space), their presence or even dominance in certain regions and on certain sites is sometimes related to other factors, such as decreased frequency of wildfires and shallow or rocky substrates.

5.2.2 Importance to Wildlife

Although shrubs in moderate to high densities may decrease the range value for cattle and sheep, their presence improves habitat quality for a variety of wildlife species because of the cover they provide and their importance as food.

"Cover" includes a number of habitat features, such as thermal cover (shade) on hot days, hiding cover for solitude and protection from predators, shelter from the wind, and nesting, perching, and feeding sites for birds and many small mammals. "Food" includes the actual leaf, stem, and fruit tissues of the shrubs for herbivores, as well as the variety of insects they support that serve as prey for songbirds and small mammals, which in turn are prey for raptors and carnivores.

The food value of big sagebrush is particularly important for pronghorn and sage grouse, two species of special concern in much of the study area because of their recreational and economic value. Both species utilize sagebrush throughout the year, but especially in winter when other food materials are either unavailable due to snow cover or low in nutrition, palatability, and digestibility. During severe winters, pronghorn and sage grouse may be almost totally dependent on sagebrush. Other shrubs typically associated with sagebrush also may be of value to wildlife. These include fourwing saltbush, shadscale, and winterfat. Although utilized by livestock and big game herbivores for browse, these species tend not to form extensive natural stands and hence are not as important overall. However, these species could potentially be useful to wildlife if they were present in abundance on revegetated lands.

Mule deer and white-tailed deer are much less common than pronghorn in sagebrush steppe ecosystems of the Northern Great Plains, and their presence in an area often is limited by the availability of shelter, water, and winter browse. In prairie areas, riparian zones and rough breaks tend to receive the greatest use by deer. In mountainous terrain, the availability of browse plants such as mountain mahogany, bitterbrush, sagebrush, serviceberry, and Gambel's oak may be limiting in winter. This also is true to some extent for elk winter range, especially in areas where snow cover precludes grazing. For both deer and elk, trees such as pinyon pine, juniper, or aspen may be critical for hiding or thermal cover, as well as for food to a lesser degree.

From the perspective of wildlife, the structural complexity of mountain shrub and some pinyon-juniper habitats generally are substantially greater than grasslands or sagebrush steppe habitats. This is because the topographic and substrate variability and higher precipitation of mountainous terrain support a larger number of woody plants, especially tall shrubs and trees. This provides an additional stratum for feeding, perching, or nesting by birds, mammals, and reptiles.

5.2.3 Other Important Aspects of Woody Plants

Besides their value for wildlife food and cover, woody plants are important for improving soil moisture and stability and serving as "refuges" for herbaceous species. Soil moisture in shrubby communities is enhanced because the woody plants (1) reduce wind speeds at the ground surface, resulting in the accumulation of snow during winter storms and lower rates of evaporation, and (2) shade the soil, thereby lowering ground surface temperatures and again decreasing the amount of moisture lost by evaporation.

In some combinations of slope and substrate, woody plants also may improve slope stability because their more massive root systems can anchor a greater volume of material than many herbaceous species. Refuges for herbaceous plants result because grazers are unable to reach grasses or forbs growing around the base of a shrub. The protected plants serve as an important seed source, particularly in situations where heavy grazing virtually eliminates the seed source in open areas between shrubs.

5.3 IMPORTANCE OF LIFEFORM AND SPECIES DIVERSITY

The vegetational diversity of an area has a direct or indirect bearing on the number of wildlife species and individuals it can support. For example, a diverse community of cool season and warm season grasses, forbs, and shrubs provides vastly more feeding and nesting sites, thermal and hiding cover, and food items than a monoculture of crested wheatgrass, which was widely used in pre-SMCRA revegetation. Moreover, a diverse community is likely to provide some sort of food value throughout the mear, which means that it may fulfill the critical needs of more individuals and more species.

Another potentially beneficial aspect of lifeform and species diversity is that it may enhance long-term survival of a plant community. In a monoculture, an environmental stress (e.g., unfavorable weather, fire, disease, or infestation) could virtually wipe out the entire stand, and consequently affect the wildlife community as well. In a diverse stand, the various plant species are able to tolerate slightly different combinations of environmental factors, so that at least some of them are likely to survive any reasonably foreseeable change in conditions. Also, the various reproductive strategies and competitive balance within a diverse plant community would enable some species to fill any void created by the decline or demise of other species. As a result, the soil and wildlife resources would be buffered from an environmental stress such as overgrazing or drought. Such reportedly is the case in the Northern Great Plains, where blue grama (Bouteloua gracilis) and buffalograss (Buchloe dactyloides) are more tolerant of drought and continue to provide soil protection and some forage when other species are in severe decline (Fults 1936, Ries and DePuit 1984).

Although it is clear that artificially created monocultures (such as early revegetated lands) lack the stability and capability for perpetuation inherent in diverse natural communities, there has been no clear demonstration of a relationship between stability and lifeform or species diversity within the range of natural plant communities. Intuitively, however, the presence of diverse organisms more fully occupies the ecological niches of a site, makes better use of the resources available, and thus more efficiently supports the native rangeland and wildlife habitat land uses. Also, because a diverse plant community is likely to include species with a variety of rooting depths, soil stability is enhanced. Therefore, performance standards relating to lifeform or species diversity are among the more important ecological aspects of revegetation.

5.4 ACHIEVEMENT OF LANDSCAPE OR COMMUNITY DIVERSITY

"Diverse" vegetational cover, as required by SMCRA, has been interpreted as referring primarily to lifeform or species diversity. However, equally important for many wildlife species is diversity of a higher order, which may be referred to as landscape or community diversity. This subject has received little attention at either the State or Federal level. The proposed shrub requirement in Wyoming for dense shrub patches on 10 percent of the mined area clearly addresses this issue, as do the practices in Montana of rehabilitating woody draws and ponderosa pine stands and in North Dakota of rehabilitating woody draws and wetlands. Informal approaches to shrub density standards in Colorado also have begun to include using mosaic plantings of shrubs to enhance community diversity.

At least three factors have worked against widespread adoption of greater landscape diversity in coal mine reclamation. First, requirements for approximate original contour have generally resulted in gently undulating land with little topographic variety, although there are exceptions. Montana DSL has approved reclamation plans that propose steep sideslopes in select areas to enhance establishment of particular plant communities, and attempts have been made at many mines to mimic features such as rimrocks with rock piles in the postmining landscape. Similarly, sections of unreduced highwall have been approved at a few mines as a means of leaving artificial cliffs or bluff extensions suitable for nesting by various raptors and other species. Nonetheless, the general lack of postmining topographic variety substantially limits the potential for community diversity at most study area mines.

Second, requirements for uniform topsoil depths over the regraded surface further homogenize site conditions and limit the potential for community diversity. At some localities, variations in topsoil depth, even to the point of no topsoil in areas intended for re-establishment of shrub communities, may be entirely appropriate. Variation in topsoil depth potentially has a strong influence on long-term plant community structure. If landscape diversity were to be encouraged, it would be necessary to allow variations in topsoil thickness. Spoil quality would of course affect consideration of decreased local topsoil depths, but in most cases poses no necessary obstacle to variable topsoil depth.

Third, the revegetation program at some mines has been kept as simple as possible to minimize costs. Requiring landscape diversity would require some additional effort, and thus cost, and probably would be opposed at these operations. However, if it were not discouraged as it currently is, then landscape diversity would be pursued at least at some mines.

5.5 ASSESSMENT OF REVEGETATION PERMANENCE

The SMCRA requirement for "permanence" of the vegetation cover has not been specifically addressed by a performance standard, although OSM believes that it is incorporated into the present system of evaluating revegetation success after a 10-year liability period. Permanence may partially be inferred by the abundance of species native to the region, which have an inherent long-term survival potential because they are adapted to conditions of climate, soil, and wildlife use. This approach apparently is followed in Montana. The response to grazing of revegetated lands bears on the permanence of the vegetation, in that the ability to withstand livestock use over the short-term is at least suggestive of an ability to do so over the long term. All states except North Dakota require test grazing of reclaimed rangeland during the last 2 years of the liability period.

Permanence also may be suggested or supported by reference to quantitative indicators. These could include (1) trends in species composition and relative abundance for the revegetated area as shown by comparing bond release test data to monitoring data from the preceding liability period; (2) long-term studies of permanent test plots, including detailed photodocumentation; (3) assessments of plant vigor, as indicated by annual growth of individual perennial plants, and of reproductive success (abundance of viable seedlings); and (4) comparisons of nutrient and mineral cycling indices in the reclaimed area versus an undisturbed area. Development of the third and, especially, the fourth types of determination listed would require input from ongoing research programs addressing the basics of ecosystem succession and stability.

The restoration of "permanent" vegetation must involve re-development of nutrient cycles and energy flows as well as the return of plant cover and production. Meeting the prescribed vegetation performance standards probably would indicate the substantial re-establishment of these processes, but verification of this relationship is yet to be accomplished.

Some research has shown that forage quality in the same species was lower on reclaimed areas than on nearby undisturbed areas (e.g., Schuman et al. 1980). It is likely that none of those samples included vegetation grown on direct haul topsoil. The forage quality on direct haul soil would be of interest as an indicator of nutrient status.

Critical to nutrient cycling and energy flow are the soil microbiota, which are unaddressed by performance standards. Their dynamics in revegetated western lands have only recently been explored (e.g., Allen 1984, Miller in press). Until the advent of direct haul topsoiling, there was very little mitigative effort, intentional or unintentional, with regard to soil microbiota. The specific ways in which the various groups of soil microbiota affect nutrient cycling and recovery of revegetated land are not yet fully known.

Also of interest in the rehabilitation of ecosystems is the degree of perturbation they can absorb without a major shift in species composition. This quality, approximating the meaning of the term "ecosystem resistance," bears on the effectiveness and permanence of the revegetation. Very little is known of this property in reclaimed lands.

Some research by Colorado State University and the Institute for Land Rehabilitation of Utah State University has begun to address such basic ecology of western revegetated areas. This type of research should provide the understanding needed to resolve the uncertainty of ecosystem re-establishment and the permanence of revegetated communities.

5.6 DEVELOPMENT OF IMPROVED PERFORMANCE STANDARD SYSTEMS FOR COVER AND PRODUCTION

Evaluation of revegetation success under SMCRA and related State laws and regulations has not yet occurred at western coal mines because the 10-year liability period has not passed at any site. Therefore, the relative merits of the various systems for evaluating revegetation success have not been tested in the field. Doubts have been raised about the effectiveness of any of the systems commonly used, including the widely followed control area and reference area systems.

As discussed in Section 4.3.1, the practicability and theoretical soundness of continuing to base performance standards on small portions of each mine permit area are questionable and thus an important issue. One possible improvement is a system known as the "extended reference area," which is being developed at case study mine WY-1 in Wyoming and is in use by a large surface mine in northwestern Colorado. This approach, based on reference areas ranging in size from tens to hundreds of acres, has two advantages. First, the improved comparability in size between reference areas and corresponding affected areas increases the representativeness of the reference area data and decreases the differences in statistical variance that accompany the present system. Second, changes in mine plans or uncontrolled actions by outside agents which might have eliminated small reference areas will have a proportionately smaller effect on large reference areas. Of course, it still is possible that a mine plan could be changed drastically enough to eliminate an extended reference area, but this is much less likely.

The extended reference area approach will not work for mines with little land outside the affected area. Even in these cases, the concept could be feasible for mining companies with separate land-holding subsidiaries that control adjacent lands or if several mines could establish extended reference areas in common which could be jointly acquired, sampled, and managed. In Montana, MDSL currently is reviewing a proposal to consolidate scattered reference areas from three mines into one reference area block that includes all premine vegetation types to be affected. Three other mines in Montana reportedly are considering this same type of proposal.

Another potential solution to the problem of establishing and maintaining performance standards is to improve technical standards. If potential climax conditions are to be used as the goal, SCS year-site data corrected for annual precipitation probably would be adequate, at least for production. If actual conditions are used to set revegetation success standards, the body of existing data from previous mine baseline studies would be a logical basis for the development of technical standards. In both cases, there are non-negligible problems with technicl details that would need careful attention.

As with SCS data, the premining baseline data are best for production, which has been sampled using fairly consistent techniques except concerning the inclusion of shrubs. In contrast, cover data in premining baseline studies have been collected using variable techniques and by observers with disparate levels of expertise. Therefore, before baseline cover data are used to set technical standards, the sometimes substantial differences in reported values between adjacent mines should be carefully analyzed to determine whether they are real or merely an artifact of the different sampling programs.

5.7 USE OF DESIGN STANDARDS IN THE REVEGETATION PROCESS

One of the primary features of SMCRA and resulting Federal regulations has been the establishment of revegetation performance standards for plant cover, production, lifeform and species diversity, permanence, and woody plant density. A source of friction between mining companies and regulatory authorities is agency insistence on particular methods of revegetation--i.e., design standards--in addition to legally required performance standards. Issues in the past have included variations in mulching and seeding and the use of introduced species. Unlike mulching and seeding, the use of introduced versus native species is specifically addressed in SMCRA (see Section 5.1, above).

From the viewpoint of the agencies, some application of design standards is desirable to ensure revegetation success and to require the use of "proven" methods is a conservative approach. On the other hand, many in industry argue that design standards stifle innovation, which must be thoroughly justified and thus creates a burden of paperwork (see Section 5.8, below). A significant improvement in the state of the art may be needlessly delayed--or potentially even prevented from emerging--if formal a priori proof of its effectiveness is not possible or so cumbersome that the proponent decides not to pursue it. Industry also feels that the risk of failure is theirs alone, because they ultimately must meet the performance standards even if their innovative methods prove unsuccessful. Moreover, their liability for failure to meet a performance standard is in no way lessened if they adhere to specific design standards.

Despite this disagreement over whether design standards are too inflexible or merely make good regulatory sense, there has been sufficient flexibility to allow significant advances in revegetation technology as a result of innovations at mines. In most cases, the innovations have been allowed by State regulatory authorities on the basis that they fall within the range of methodological flexibility and are not "experimental practices" with the attendant formalities required by OSM.

5.8 ROLES OF INDUSTRY AND REGULATORY AUTHORITIES IN INNOVATION

5.8.1 Overview

Innovation at the mines has been responsible for some of the most important advances in western surface coal mine revegetation during the past two decades. Innovation has come in large part from mine revegetation personnel who modify procedures based on field experience under the conditions at a particular mine. Government-sponsored research, often carried out by or in cooperation with state university contractors, has sometimes been a source of ideas that are then tested and refined at the mines.

Federal and State regulatory authorities generally have not had a substantial role in originating innovative revegetation ideas or procedures, although by members of the NDPSC contributed to the development of techniques for re-establishing woody draws at case study mine ND-1. State agencies have often encouraged the use of successful innovations that have come to their attention, thereby speeding their development. State regulatory personnel have contributed original innovation in their area of expertise--regulation. Negotiated technical standards for woody plant density and species or lifeform diversity represent the fruits of regulatory innovation.

The results of the interview phase of this study reveal that mine revegetation personnel tend to view innovation as being stifled by the regulations. Industry's perspective is underlain by frustration, beginning with the fact that the "experimental practice" provision of SMCRA is such a complex and time-consuming procedure that it has proven feasible only when major engineering practices and potential major cost savings are involved.

Many State regulatory agency personnel also express frustration because they feel that the regulations unduly restrict their ability to allow innovation. In numerous other cases, they reportedly have encouraged innovation only to have mine management opt for a "safer" approach.

Within each state, requests for variation from approved permit procedures are treated within the context of minor permit revisions if the proposed practice is precedented elsewhere, although very recent innovations usually require documentation by the mining company. For requests unprecedented elsewhere (original innovation), field trials usually are required to scientifically prove that the new procedure will be at least as effective as the one it replaces. Mining companies feel that they are responsible for achieving an end product, i.e., the performance standards, but that how they do it is their business. In at least one case, a sophisticated mining company that collects considerable internal data on the relative success of various revegetation practices has had difficulty in getting an innovation approved because they did not formally originate the experiment under field trials reviewed and approved by the State. Thus an innovative and demonstrably effective technique is not being applied, to the detriment of all concerned. See the following section, 5.8.2.

Part of industry's view is related to their perception of many regulatory personnel as being comparatively inexperienced. Agency staff members often are recent graduates with limited hands-on revegetation experience, particularly regarding the specific situations at operating mines. In contrast, reclamation coordinators at the mines usually have had the benefit of considerable field experience and many have become thoroughly familiar with the ecological characteristics and revegetation problems of their mine and the region. High turnover rates within regulatory agencies aggravate the problem of regulatory staff inexperience, as regulators have moved to higher paying jobs elsewhere. Therefore, coal company reclamation personnel are concerned that their requests for permission to use an innovative practice are judged by persons without sufficient experience and perspective.

Another phenomenon that increases the likelihood of disagreement between industry and regulators is an information "lag effect," in which knowledge of new findings or implications of monitoring data only gradually diffuse to the regulatory personnel. The secretiveness of some companies regarding monitoring data harms industry interests by lowering the level of common knowledge. There is somewhat more rapid information transfer among coal company reclamation specialists, who often have shared their findings with colleagues involved in reclamation work at other mines in their region.

The inevitable differences in the approaches preferred by different people frequently have led coal company personnel to develop a feeling of resentment toward the regulatory control of innovation. Many regulatory authorities are becoming aware that some of the industry views have validity and that supplemental technical training for their staffs is desirable. It should be pointed out that industry reclamation specialists who become very familiar with their mines and nearby mines may lack the perspective of the regulator in addressing problems state-wide. Industry could improve conditions by beginning to more carefully document their revegetation techniques and monitoring data, and to freely disseminate their findings among other companies and regulatory agencies.

Complaints by mine personnel about the stifling of innovation often are related to dissatisfaction with the designated postmining land uses. With the exception of North Dakota, postmining land uses are almost automatically designated as native rangeland and wildlife habitat rather than improved pastureland. This results in what some in industry believe are needless concerns with the establishment of native species, diversity, and woody plant density.

Preserving the freedom to innovate is critical for continued progress in revegetation technology, and, at least psychologically, to continued conscientious revegetation in general. The best revegetation plans will have poor results if applied by persons not personally committed to good revegetation, i.e., persons responding to a cookbook recipe dictated to them. The dedication of the mine revegetation specialist to careful observation of field conditions, and the implementation of small or large changes in technique in the interest of more sensible and effective horticulture, are immensely important to revegetation success.

Whether a particular mine employs advanced revegetation technology also relates to the mine management situation. At some mines, the revegetation specialist is given sufficient authority to implement a new procedure even though it may necessitate modification of engineering procedures. At other mines, the prevalence in management positions of engineers who are unfamiliar with advanced revegetation technology makes the implementation of new revegetation procedures affecting the engineering status quo almost impossible.

5.8.2 "Seeding" with Live Topsoil

A situation at case study mine CO-1 is illustrative of a conflict where both the mining company and the regulatory authority are restricted by regulations written at a time when improvements in revegetation technology were not foreseen. At issue is a request by the mine to have the seeding requirement waived on areas receiving direct haul topsoil. The company asserted that seeding was unnecessary because of abundant volunteer growth from seeds and vegetative parts within the relocated soil. Along with the request, the company submitted 3 years of monitoring data to substantiate their claim.

The State regulatory authority, although cognizant of the effectiveness of the treatment, was unable to grant the waiver because to do so would have conflicted with the requirement for seeding or planting in CFR 816.111(b)(1) and requirements for prior regulatory approval of field trial design. The company responded that the presence of viable seeds and potentially regenerative roots in the soil constitutes seeding and planting and leads to the establishment of plants better adapted to the site than are available in mixes of commercially available seed.

The State regulatory authority, in its reticence to grant the requested waiver, apparently was reluctant to set a precedent that could lead to similar requests in areas that were not as clearly suitable for this procedure. Their concern about the precedential effect is supported by the fact that such a waiver would occur without formal completion of the field trial process mandated by State regulations.

Thus, although both parties agreed upon the value of the proposed treatment, the regulatory formalities intended to ensure good reclamation had the effect in this case of impeding a technological advance. At present, the two parties have agreed to handle the matter as a technical revision, which will allow formal approval of the proposed practice as a field trial.

5.9 COLLECTION AND USE OF MONITORING DATA

Most coal companies collect at least some monitoring data, illustrating wide acceptance of the need for tracking the progress of revegetation so that problems are quickly recognized and modifications in methods can be made to improve current and future results. The monitoring data also may be used to evaluate the successional progress of the postmining plant communities and, eventually, to adjust livestock stocking rates. However, mining personnel frequently are reluctant to release their data out of concern that any revegetation problems or weak points will result in administrative difficulties.

In contrast to the positive attitude toward monitoring data of most coal companies are a few mine personnel who see little potential benefit from monitoring and view it only as a burden or or unnecessary expense or who are mainly concerned about their legal liability and public relations.

Regulatory authorities generally have said that they would like to receive monitoring data in order to gauge the site-specific strengths and weaknesses of different revegetation procedures. If the data were on file at the agency offices, other interested parties (e.g., other mines) could benefit from the new knowledge and possibly utilize it to enhance their reclamation. With increased information flow, there is a greater chance of reaching a consensus on how potential problems should be dealt with, a greater chance that solutions to the problems will be found, and, in the long run, less probability of serious conflict with the regulatory authority.

5.10 APPROPRIATENESS OF STATISTICAL METHODS

Throughout the history of quantitative performance standards for surface coal mine revegetation, there has been controversy over the statistical methods used. This debate has centered on two aspects of the process: (1) statistics for determination of sample adequacy, and (2) statistics for determination of revegetation success and of comparability between reference areas and affected areas. Only a brief review of the statistical issues is possible in this report. Detailed treatment of statistical aspects of sample adequacy can be found in Keammerer (1983) and Sowards (1983).

Calculation of sample adequacy has been based on requirements that the data detect a given percent reduction in the mean with a given percent confidence. These requirements for sample adequacy are not specifically stated in SMCRA or the 1979 Permanent Regulatory Program. However, the statistical requirements of the revegetation performance standards in the 1979 Federal Regulations [CFR 816.116(b)(3)] have been applied to sample adequacy by OSM and the State regulatory authorities.

The 1979 Federal regulations concerning revegetation success state that ground cover and productivity of the revegetated area shall be considered equal if they are at least 90 percent of the values in the reference area with 90 percent confidence (80 percent confidence in shrublands). Although not dealing with sample adequacy, these figures have been used by regulators in sample adequacy formulas. Thus, the descriptive form of the sample adequacy criteria used by regulators is that sample size must be adequate to detect a 10 percent reduction in mean with 90 percent confidence (80 percent in shrublands, although this varies by state). The net effect of this is that required sample sizes have been very high, generally exceeding levels considered adequate for academic research. It should be noted that most states have instituted ceilings on sample size so that absurd numbers of samples are not taken even if "required" by the adequacy calculations.

Alternative methods of assessing sample adequacy could include use of standard error as a percent of the mean or variation of running means.

The comparison of affected (or revegetated) area values to reference area values typically has been accomplished by use of a t-test (see Larson 1980). This statistical method traditionally has been used to test for a significant difference between two sets of data. Its use to detect "sameness" (i.e., to prove comparability) results in the seemingly backwards situation of being able to more easily "prove" equality with higher degrees of confidence (higher values of t). Thus, regulators are faced with requiring nominally lower confidence limits in order to maintain test stringency. The use of alternative means of testing for achievement of quantitative performance standards has only begun to be explored (e.g., see Steward 1983).

5.11 BOND RELEASE

The last two revegetation regulatory issues identified during this study deal with the 10-year liability period and phased bond release for native rangeland and wildlife habitat.

The issue related to the 10-year liability period concerns the question of what types of horticultural practices may effectively "reset the clock." The regulatory principle is that vegetation at the end of the liability period should be self-sustaining and thus have developed without intensive on-going management such as fertilizing, replanting, or spraying for weeds, other than as necessary for initial establishment of the stand. A problem could potentially arise if, for example, a mine were to conduct some vegetation management activity in Year 8 that the regulatory authority deems to exceed the permitted level of intensity. Theoretically, the liability period "clock" would be "reset" to Year 1, effectively delaying final bond release by eight years.

For most states, the regulatory limit on management is that only "normal husbandry" practices are permitted. Although the term is not well defined agencies have not yet faced a problem requiring careful definition. In North Dakota and Montana the regulations do not explicitly specify that "normal" husbandry practices are acceptable. In practice, North Dakota has not "restarted" the clock for such practices. Montana's policy is not clearly defined.

The other bond release issue deals with the present phasing system in which approximately 60 percent of the bond amount is released following regrading and topsoiling, and as little as 15 percent may remain by the time revegetation performance is tested. While this may be reasonable based on the distribution of costs during the reclamation process (earth moving is very expensive), it may not leave enough bond money for a comprehensive remedial program in the event of a substrate-related revegetation failure.

The adequacy of soil (and shallow overburden) handling and treatment is judged primarily by the achievement of successful revegetation (see the companion report on soils and overburden). It therefore seems of dubious validity for bond release to be phased in a way that preserves only enough money for reseeding or perhaps minor soil treatments.

5.12 FUTURE RESEARCH PRIORITIES

This section briefly describes the highest priorities for revegetation research and is in no way an exhaustive listing of desirable research topics. Research needs related to soils/overburden and wildlife are discussed by Walsh and Associates (1985) and Cedar Creek Associates (1985), respectively. A survey of research and list of research topics for North Dakota that are applicable for most of the northern part of the study area was prepared by the Reclamation Research Advisory Council and North Dakota Public Service Commission (1984).

Two general realms of revegetation research are identified here: revegetation technology and revegetation performance standards. In the realm of revegetation technology, continued improvements will depend primarily upon continued studies at mine sites already revegetated, in order to evaluate their long-term characteristics, especially stability. Sites with problem soils or very low or erratic precipitation also are high priorities for ongoing research.

In terms of specific technologies, one of the more important research topics for re-establishing native rangeland and wildlife habitat is the relative value of preserving a biologically active topsoil, such as by direct haul topsoiling. At many mines, careful identification and separate handling of the most beneficial surface soil layers, without dilution by underlying subsoil, might improve revegetation sufficiently to justify the cost. Sites with benign spoil could potentially be equivalently or better revegetated by omitting the salvage of subsoil and by careful live handling of the biologically active surface layer. DePuit (1984) and Walsh and Associates (1985) discuss some of these possibilities. Ideally, procedures of soil handling should also facilitate the recovery of below ground ecosystem processes by conservation of active soil micro-organisms which are critical for ongoing nutrient cycling, and thought to affect the long-term success of revegetation. Further research on direct haul versus long-term topsoil storage would be valuable in more thoroughly addressing these questions, and especially in documenting regions, soils, and other situations in which the direct haul technique is desirable or undesirable.

In the realm of revegetation performance standards, there needs to be a focus on functional and not merely descriptive standards that are applicable in the field and legally defensible. Specific needs include the following:

- a better means of adjusting cover and production performance standards for year-to-year changes in climate or other environmental factors;
- a better means of measuring and judging the attainment of diversity on revegetated lands, including landscape diversity, as well as lifeform and species diversity, in addition to a better understanding of the time needed to re-establish diversity;
- a carefully reasoned approach to judging the success or failure of achieving vegetation permanence, including a critical evaluation of test grazing on revegetated rangelands.

SECTION 6.0

REFERENCES

7.0 REFERENCES

Aldon, E. F. 1984. Vegetation parameters for judging the quality of reclamation on coal mine spoils in the southwest. Great Basin Naturalist 44(3):441-446.

Aldon, E. F. 1983. Methods for establishing fourwing saltbush on disturbed sites in the southwest. In: Proc. - Symp. on the Biology of Atriplex and Related Chenopods. A. R. Tiedemann, E. D. McArthur, H. C. Stutz, R. Stevens, and K. L. Johnson (compilers). U.S. For. Serv., Internal For. and Rge. Exp. Sta., Gen Tech. Rep. INT-172.

Aldon, E. F. 1981. Long-term plant survival and density data from reclaimed southwestern coal mine spoils. The Great Basin Naturalist 41(3): 271-273.

Aldon, E. F. 1978. Reclamation of coal-mined land in the southwest. J. of Soil and Water Conservation 33(2):75-79.

Aldon, E. F. 1977. Endomycorrhizae enhance shrub growth and survival on mine spoils. In: The Reclamation of Disturbed Arid Lands. R. A. Wright (ed.), Univ. of N. Mex. Press, Albuquerque, NM.

Aldon, E. F. 1977. Survival of three grass species after inundation. U.S. For. Serv., Rocky Mt. For. and Rge. Exp. Sta. Res. Note RM-344, Fort Collins, CO.

Aldon, E. F. 1975. Endomycorrhizae enhance survival and growth of fourwing saltbush on coal mine spoils. U.S. For. Serv. Rocky Mt. For. and Rge. Exp. Sta. Res. Note RM-294, Fort Collins, CO.

Aldon, E. F. 1975. Establishing alkali sacaton on harsh sites in the southwest. J. Range Manage. 28(2):129-132.

Aldon, E. F. 1972. Critical soil moisture levels for field planting fourwing saltbush. J. of Range Manage. 25(4):311-312.

Aldon, E. F., O. D. Knipe, and G. Garcia. 1973. Revegetating devastated sites in New Mexico with western wheatgrass transplants. U.S. For. Serv., Rocky Mt. For. and Rge. Exp. Sta. Res. Note RM-243, Fort Collins, CO.

Aldon, E. F., H. W. Springfield, and W. E. Sowards. 1976. Demonstration test of two irrigation systems for plant establishment on coal mine spoils. p. 201-214 In: Fourth Symp. on Surf. Min. and Reclam. NCA/BCR Coal Conf. and Expo III, Natl. Coal Assoc., Washington, D.C.

Allen, E. B. 1984. Role of mycorrhizae in mined land diversity. In: Proc. Third Biennial Symp. on Surface Coal Mine Reclamation on the Great Plains, Billings, MT, p. 273-295.

Amendola, F. A., M. D. Mitchell, and D. W. Simpson. 1984. Reclamation of tree and shrub species at the Absaloka Mine. In: Proc. Third Biennial Symp. on Surface Coal Mine Reclamation on the Great Plains, Billings, MT, p. 237-250.

Bailey, R. G. 1980. Description of the ecoregions of the United States. U.S. For. Serv. Misc. Publ. 1391, Ogden, UT.

Barbour, M. G., J. H. Burk, and W. D. Pitts. 1980. Terrestrial plant ecology. The Benjamin/Cummings Publishing Company, Inc.

Barth, R. C. and B. K. Martin. 1982. Soil-depth requirements to reclaim surface-mined areas in the Northern Great Plains. Colorado School of Mines Research Institute, Environmental Technology Division, Golden, CO.

Biermann, B. and R. G. Linderman. 1983. Use of vescicular-arbuscular mycorrhizal roots, intraradical vesicles and extraradial vesicles as inoculum. New Phytol. 95:97-105.

Biermann, B. J. 1982. Inoculation of container plants with VAM mycorrhizae. In: VA Mycorrhizae and Reclamation of Arid and Semi-arid Lands. Williams, S. E. and M. F. Allen (eds.), Proc. of the Conf., Dubois, WY. Wyo. Agr. Exp. Sta. Rep. SA1261.

Bituminous Coal Research, Inc. 1974. Glossary of surface mining and reclamation technology. National Coal Association (publisher), Louisville, KY.

Bjugstad, A. J. 1984. Shrubs and tree establishment on coal spoils in the northern high plains. Proc. Third Biennial Symp. on Surface Coal Mine Reclamation on the Great Plains, Billings, MT, p. 223-236.

Bjugstad, A. J. 1977. Re-establishment of woody plants on mine spoils and management of mine water impoundments: an overview of Forest Service research on the northern high plains. In: Reclamation of Disturbed Arid Lands. R. A. Wright (ed.), Univ. N. Mex. Press, Albuquerque, NM.

Bjugstad, A., T. Yamamoto, and D. Uresk. 1981. Upland shrub establishment on coal and bentonite clay mine spoils. In: Proc. of the Shrub Establishment Symp., Wyo. Game and Fish Dept., Cheyenne, December 2-3, 1980, Laramie, WY, p. 104-122.

Bonham, C. D., L. Larson, and A. Morrison. Draft. A survey of techniques for measurement of herbaceous and shrub production, cover, and diversity on coal lands in the west. OSM, Denver, CO.

Booth, D. T. 1984. Innovation in wildland shrub establishment. In: Proc. Third Biennial Symp. on Surface Coal Mine Reclamation on the Great Plains, Billings, MT, p. 251-257.

Bradshaw, A. D. and M. J. Chadwick. 1980. The restoration of land: the ecology and reclamation of derelict and degraded land. Univ. of Calif. Press, Berkeley, CA.

Bray, J. R. and J. T. Curtis. 1957. An ordination of upland forest communities of southern Wisconsin. Ecol. Monogr. 27:325-349.

Brown, D. 1977. Handbook of equipment for reclaiming strip mined land. U.S. For. Serv., Equipment Development Center, #7728 2503, Missoula, MT.

Brown, D. and R. G. Hallman. 1984. Reclaiming disturbed lands. U.S. For. Serv., Equipment Development Center, Missoula, MT.

Brown, R. W. 1980. Revegetation with native and introduced plant species. 26th Grass Breeders Conference,, Utah St. Univ., Logan, UT.

Buckner, D. L. 1983. Combining measures of spatial and temporal variation: a historical record approach to obtaining baseline data. In: Western Reclamation Group Symp. on Western Coal Mining Regulatory Issues: Land Use, Revegetation and Management. E. F. Redente, W. E. Sowards, D. G. Steward, and T. L. Rutier (eds.), Colo. St. Univ. Rge. Sci. Dept., Sci. Ser. No. 35, Fort Collins, CO, p. 84-86.

Bunin, J. 1983. Transplanting offers reclamation solutions. Coal Mining and Processing 20(6):24-28.

Bunin, J., J. Hackos, and M. Harthill. 1982. Sodding native grasslands for mined land reclamation in the Northern Great Plains. Mineral and Energy Resources 25(3). Colorado School of Mines, Golden, CO.

Burroughs, E. R., Jr., M. D. Scott, and D. F. Gibson. SEAMPLAN. A computer based mine and reclamation planning system. U.S. For. Serv. Misc. Publ. INT-1. U.S. For. Serv. Intermt. For. and Rge. Exp. Sta., Ogden, UT.

Cable, D. R. 1977. Western wheatgrass transplants grow well on raw mine spoils. U.S. For. Serv., Rocky Mt. For. and Rge. Exp. Sta., Res. Note RM-345, Fort Collins, CO.

Carlson, K. E., J. L. Smith, and K. A. Crofts. 1981. Transplanting mature vegetation in mine reclamation. Presented at 1981 Rocky Mt. Sect., Amer. Soc. of Agr. Eng., Univ. of Wyo., Laramie, WY.

Cedar Creek Associates. 1985. Wildlife technologies for western surface coal mining. Prepared for OTA.

Chambers, J. 1983. Measuring species diversity on revegetated surface mines: an evaluation of techniques. U.S. For. Serv., Intermt. For. and Rge. Exp. Sta., Res. Pap. INT-322, Ogden, UT.

Chambers, J. and R. Brown. 1983. Methods for vegetation sampling and analysis on revegetated mined lands. U.S. For. Serv., Intermt. For. and Rge. Exp. Sta., Gen. Tech. Rep. INT-151, Ogden, UT.

Code of Federal Regulations - Mine Resources. 30 CFR, Part 700-end, rev. July 1, 1984.

Coenenberg, J. 1982. Methods for establishment of diverse native plant communities at the Rosebud Mine. In: Symp. on Surface Coal Mining and Reclamation in the Northern Great Plains, Billings, MT. Mont. Agr. Exp. Sta. Res. Rep. No. 194.

Colling, G. (compiler). 1980. Bibliography of SEAM publications. USDA For. Serv., Intermt. For. and Rge. Exper. Sta., Gen. Tech. Rep. INT-88, Ogden, UT.

Colorado Department of Natural Resources - Mined Land Reclamation Division (CMLR). 1980 (Revised 1983). Regulations of the Colorado Mined Land Reclamation Board for coal mining.

Colorado, State of. 1983. Colorado Surface Coal Mining Reclamation Act (formerly Colorado Open Mining Land Reclamation Act of 1973).

Cook, C. W. and C. D. Bonham. 1977. Techniques for vegetation measurements and analysis for a pre- and post-mining inventory. Colo. St. Univ. Rge. Sci. Dept., Science Series No. 28, Fort Collins, CO.

Cook, C. W., R. M. Hyde, and P. L. Sims. 1974. Guidelines for revegetation and stabilization of surface mined areas in the western states. Colo. St. Univ. Rge. Sci. Dept., Science Series No. 16, Fort Collins, CO.

Crofts, K. A. 1981. The nonconcepts of species diversity and woody plant density as revegetation success standards. In: Proc. of the Northwest Colorado Land Reclamation Seminar II. Colo. St. Univ. Ext. Serv., Fort Collins, CO.

Crofts, K. A. and K. E. Carlson. 1982. Transplanting techniques used in the establishment of native vegetation. In: Proc. High-altitude revegetation workshop No. 5. R. L. Cuany and J. Etra (eds.). Colo. St. Univ. Info. Ser. No. 48, Fort Collins, CO.

Crofts, K. A. and C. M. McKell. 1977. Sources of seeds and planting materials in the western states for land rehabilitation projects. Utah Agr. Exp. Sta. Land Rehab. Ser. No. 4, Logan, UT.

Crofts, K. A. and C. R. Parkin. 1979. Methods of shrub and tree establishment on strip mined lands in northwest Colorado. Paper presented before the Symp. on Surface Coal Mining and Reclamation.

Dalsted, N. L. and F. L. Leistritz (compilers). 1973. A selected bibliography on surface coal mining and reclamation of particular interest to the great plains states. N. Dak. St. Univ. Agr. Exp. Sta., Fargo, ND.

Darling, A. P. and S. A. Young. 1984. The effects of native hay mulch on soil stabilization and introduction of native species on strip mined lands in southeastern Montana. In: Proc. Third Biennial Symp. on Surface Coal Mine Reclamation on the Great Plains, Billings, MT, p. 296-306.

DePuit, E. J. 1984. Potential topsoiling stragegies for enhancement of vegetation diversity on mined lands. In: Third Biennial Symp. on Surface Coal Mine Reclamation on the Great Plains, Billings, MT, p. 258-272.

DePuit, E. J. 1982. Cool season perennial grass establishment on Northern Great Plains mined lands: status of current technology. In: Symp.on Surface Coal Mining and Reclamation in the Northern Great Plains, Billings, MT. Mont. Agr. Exp. Sta., Res. Rep. No. 194.

DePuit, E. J. and J. G. Coenenberg. 1979. Responses of revegetated coal strip mine spoils to variable fertilization rates, longevity of fertilization program, and season of seeding. Mont. Agr. Exp. Sta. Res. Rep. No. 150.

DePuit, E. J., J. G. Coenenberg, and C. L. Skilbred. 1980. Establishment of diverse native plant communities on coal surface-mined lands in Montana as influenced by seeding method, mixture, and rate. Mont. Agr. Exp. Sta., Res. Rep. No. 163.

DePuit, E. J., C. L. Skilbred, and J. G. Coenenberg. 1982. Effects of two years of irrigation on revegetation of coal surface-mined land in southeastern Montana. J. of Range Manage. 35(1):67-74.

DePuit, E. J., W. W. Willmuth, and J. G. Coenenberg. 1977. Plant response and forage quality for controlled grazing and coal mine spoils pastures. 1976 Progress Report. Reclamation Research Unit, Mont. Ag. Exp. Sta.

Dittberner, P. L. and M. R. Olson. 1983. The plant information network (PIN) data base: Colorado, Montana, North Dakota, Utah, and Wyoming. U.S. Fish and Wildl. Serv., FWS/OBS-83/36.

Doerr, T. B., E. F. Redente, and T. E. Sievers. 1983. Effect of cultural practices on seeded plant communities on intensively disturbed soils. J. Range Manage. 36:423-428.

Doll, E. C., S. D. Merrill, and G. A. Halvorson. 1984. Soil replacement for reclamation of strip mined lands in North Dakota. N. Dak. Agr. Exp. Sta. Bull. No. 514.

Doll, E. C., N. C. Wollenhaupt, G. A. Halvorson, and S. A. Schroeder. 1984. Planning and evaluating cropland reclamation after strip mining in North Dakota. Minerals and the Environment 6:121-126.

Draves, R. W. and W. A. Berg. 1975-1978. Establishment of native shrubs on disturbed lands in the mountain shrub vegetation type. Colo. St. Univ. Agron. Dept. and Agr. Exp. Sta., Fort Collins, CO.

Eddleman, L. E. 1982. Research on shrub establishment in reclamation of surface mined lands. In: Symp. on Surface Coal Mining and Reclamation in the Northern Great Plains, Billings, MT, Mont. Agr. Exp. Sta. Res. Rpt. No. 194.

Ferguson, R. B. and N. C. Frischknecht. 1981. Shrub establishment on reconstructed soils in semi-arid areas. In: Shrub establishment on disturbed arid and semi-arid lands; proc. of symp. at Laramie, WY, Dec. 2-3, 1980, p. 57-63, Wyoming Game and Fish Dept.

Frischknecht, N. C. and R. B. Ferguson. 1979. Revegetating processed oil shale and coal spoils on semi-arid lands. U.S. Environmental Protection Agency EPA-600/7-79-068.

Fulton, G. W., W. I. Barker, and A. J. Bjugstad. 1983. Rooted aquatic plant revegetation of strip mine impoundments in the Northern Great Plains. In: Proc., Third Plains Aquatic Research Conf., Aug. 24-25, 1983, Bozeman, MT, Inst. of Nat. Res., Mont. St. Univ.

Fults, J. L. 1936. Blue grama grass for erosion control and range reseeding in the Great Plains and a method of obtaining seed in large lots. Circ. 402. USDA, Washington, D.C.

Garcia, G. 1979. A portable irrigation system for remote sites. U.S. For. Serv. Rocky Mt. For. and Rge. Exp. Sta. Res. Note RM-374.

Goodman, D. 1975. The theory of diversity-stability relationships in ecology. The Quart. Rev. Biol. 50(3):237-266.

Gough, L. P. and R. C. Severson (eds.). 1982. Trace element mobilization in western energy regions. In: Proc. of a Symp. Stressing the Application of Data to Problems in Arid and Semi-arid Environments. Denver, CO.

Hansen, D. 1982. Reclamation planting of disturbed sites. Native Plants, Inc., Salt Lake City, UT.

Harniss, R. D., S. J. Harvey, and R. B. Murray. 1981. A computerized bibliography of selected sagebrush species (genus Artemisia) in western North America. U.S. For. Serv. Intermt. For. and Rge. Exp. Sta., Gen. Tech. Rep. INT-102.

Hartley, D. M. and G. E. Schuman. 1984. Soil erosion potential of reclaimed mined lands. Transactions of the ASAE 27(4):1067-1073. Amer. Soc. of Agr. Eng., St. Joseph, MI.

Hartman, R. L. and K. H. Dueholm. 1979. Catalogue of vascular plants of the Powder River Basin, Wyoming. Institute of Energy and Environment, Univ. of Wyo., Laramie, WY.

Herron, J. T. and W. A. Berg. 1975-1977. Establishment of native shrubs on disturbed lands in the mountain shrub vegetation type. Colo. St. Univ. Agron. Dept., Agr. Exp. Sta., Fort Collins, CO.

Hofmann, L. and R. E. Ries. 1980. Comparison of vegetative composition, cover and production on reclaimed and non-mined grazing lands. In Adequate Reclamation of Mined Lands? Symp. Proc., SCS, Billings, MT, p. 27-1 to 27-10.

Hofmann, L., R. E. Ries, and J. E. Gilley. 1983. Relationship of runoff and soil loss to ground cover of native and reclaimed grazing land. Agronomy Journal 75:599-602, July-August.

Hofmann, L., R. E. Ries, and R. J. Lorenz. 1981. Livestock and vegetative performance on reclaimed and non-mined rangeland in North Dakota. J. of Soil and Water Conservation 36(1):41-44.

Hofmann, L., R. E. Ries, J. F. Power, and R. J. Lorenz. 1978. Influence of frame quadrat orientation on vegetation analyses obtained on disturbed land reseeded in rows. In Proc. of the First International Rangeland Congress, p. 521-523.

Holecheck, J. L., E. J. DePuit, J. G. Coenenberg, and R. Valdez. 1981. Fertilizer effects on establishment of two seed mixtures on mined land in southeastern Montana. J. Soil and Water Conservation, 36:241-245.

Holecheck, J. L., E. J. DePuit, J. G. Coenenberg, and R. Valdez. 1982. Legume establishment on strip mined lands in southeastern Montana. J. of Range Manage. 35(3):298-300.

Howard, C. and S. Regele. 1984. Reclamation monitoring: its purpose and scope. In: Proc. Third Biennial Symp. on Surface Coal Mine Reclamation on the Great Plains, Billings, MT, p. 330-334.

Howard, G. S. and M. J. Samuel. 1979. The value of fresh-stripped topsoil as a source of useful plants for surface mine revegetation. J. of Range Manage. 32(1):76-77.

Institute for Land Rehabilitation. 1984. Reclamation research. Utah St. Univ., Logan, UT.

Institute for Land Rehabilitation. 1979. Selection, propagation, and field establishment of native plant species on disturbed arid lands. Utah Agr. Exp. Sta. Bull. 500.

Institute for Land Rehabilitation. 1978. Rehabilitation of western wildlife habitat: a review. U.S. Fish and Wildl. Serv. FWS/OBS-78/86.

Institute of Natural Resources. 1983. Proc. Third Plains Aquatic Research Conf. Aug. 24-25, 1983, Mont. St. Univ., Bozeman, MT.

Iverson, L. R. and M. K. Wali. 1982. Reclamation of coal mined lands: The role of *Kochia scoparia* and other pioneers in early succession. Recl. Reveg. Res. 1:123-160.

Jastrow, J. D., R. M. Miller, S. C. Rabatin, and R. R. Hinchman. (in press). Revegetation of disturbed land in arid ecosystems. *In*: Ecological Studies of Disturbed Landscapes. A Compendium of the Results of Five Years of Research Aimed at the Restoration of Disturbed Ecosystems. U.S. Dept. of Energy.

Jensen, I. and R. Hodder. 1979., Tubelings, condensation traps, mature tree transplants, and root sprigging techniques for tree and shrub establishment in semi-arid areas. Mont. Agr. Exp. Sta. Res. Rep. 141, Missoula, MT.

Keammerer, W. R. 1983. Measures of sample adequacy. *In*: Western Reclamation Group Symp. on Western Coal Mining Regulatory Issues: Land Use, Revegetation and Management. E. F. Redente, W. E. Sowards, D. G. Steward, and T. L. Ruiter (eds.). Colo. St. Univ. Rge. Sci. Dept., Sci. Ser. No. 35, Fort Collins, CO.

Klipple, G. E. 1964. Early- and late-season grazing versus season-long grazing of short-grass vegetation on the Central Great Plains. U.S. For. Serv. Rocky Mtn. For. and Rge. Exp. Sta. RM-11, Fort Collins, CO.

Kuchler, A. W. 1966. Potential natural vegetation of the United States. American Geographic Society Spec. Pub. 361, New York.

Lang, R. (compiler). 1971. Reclamation of strip mine spoil banks in Wyoming. Univ. of Wyo., Agr. Exp. Sta., Res. Jour. 51, Laramie, WY.

Larson, J. 1982. History of the vegetative rehabilitation and equipment workshop (VREW), 1946-1981. U.S. For. Serv. Equipment Development Center, Missoula, MT.

Larson, J. E. 1980. Revegetation equipment catalog, prepared for the Vegetative Rehabilitation and Equipment Workshop (VREW), U.S. For. Serv. Equipment Development Center, Missoula, MT.

Larson, L. 1980. Draft. A statistical evaluation of revegetation success on coal lands in the west. OSM, Denver, CO.

Lindsey, D. L., W. A. Cress, and E. F. Aldon. 1977. The effects of endomycorrhizae on growth of rabbitbrush, fourwing saltbush, and corn in coal mine spoil material. U.S. For. Serv., Rocky Mt. For. and Rge. Exp. Sta., Res. Note RM-343, Fort Collins, CO.

Long, S. G., J. K. Burrell, N. M. Laurenson, and J. H. Nyenhuis. 1984. Manual of revegetation techniques. Cut-and-fill slopes. Mined lands. Watershed projects. Range improvement. U.S. For. ServO, Equipment Development Center, Missoula, MT.

Luke, F. and S. B. Monsen. 1983. Methods and costs for establishing shrubs on mined lands in southwestern Wyoming. In: Proc. - Symposium on the Biology of Atriplex and Related Chenopods. A. R. Tiedemann, E. D. McArthur, H. C. Stutz, R. Stevens, and K. L. Johnson (compilers). U.S. For. Serv., Intmt. For. and Rge. Exp. Sta., Gen. Tech. Rep. INT-172, Ogden, UT.

McArthur, E. D. 1981. Shrub selection and adaptation for rehabilitation plantings. In: Proc. of the Symp.. Shrub Establishment on Disturbed Arid and Semi-arid Lands. Wyoming Game and Fish Dept., Cheyenne, WY.

McGinnies, W. J., W. G. Hassell, and C. H. Wasser. A summary of range seeding trials in Colorado. Colo. St. Univ. Cooperative Ext. Ser., Special Series No. 21, Fort Collins, CO.

McGinnies, W. J. and P. J. Nicholas. 1980. Effects of topsoil depth and nitrogen fertilizer on the revegetation of coal mine spoils. J. Environ. Quality 9:681-685.

Miller, R. M. (in press). Microbial ecology and nutrient cycling in disturbed arid ecosystems. In: Ecological Studies of Disturbed Landscapes. A Compendium of the Results of Five Years of Research Aimed at the Restoration of Disturbed Ecosystems. U.S. Dept. of Energy.

Miller, R. V., E. E. Staffeldt, and B. C. Williams. 1979. Microbial populations in undisturbed soils and coal mine spoils in semi-arid conditions. U.S. For. Serv. Rocky Mt. For. and Rge. Exp. Sta., Res. Note RM-372, Fort Collins, CO.

Monsen, S. B. 1975. Selecting plants to rehabilitate disturbed areas. In: Improved Range Plants. Campbell, R. S. and C. H. Herbel (eds.), p. 76-90. Range Symp. Ser. 1, Soc. Range Manage., Denver, CO.

Monsen,S. B. and A. Plummer. 1978. Plants and treatment for revegetation of disturbed sites in the Intermountain area. In: The Reclamation of Disturbed Arid Lands, Wright, R. A., ed., Univ. of N. Mex. Press, Albuquerque, NM.

Montana, Department of State Lands (MDSL). 1980 (Revised 1984). Montana's permanent program strip and underground mine reclamation rules and regulations, Helena, MT.

Montana, Department of State Lands (MDSL). 1980. Draft vegetation guidelines, Helena, MT.

Montana, State of. 1973 (Revised 1983). Montana Strip and Underground Mine and Reclamation Act. Title 82, Chapter 4, Part 2, MCA.

Moore, R. and T. Mills. 1977. An environmental guide to western surface mining. Part Two: Impacts, mitigation, and monitoring. U.S. Fish and Wildl. Serv., FWS/OBS-78/04.

Motyka, J., R.o Dobrzanski,and S. Zawadski. 1950. Wstepne badanla nad lakami paludniowo-wschodneij Lubelszczynzyn. [Preliminary studies on meadows in the southwest province Lublin.] Ann. Univ. M Curie-Sklowdowska, Sec. E5:367-447.

Mueller-Dombois, D. and H. Ellenberg. 1974. Aims and methods of vegetation ecology. New York: John Wiley and Sons.

Munshower, F. F. and S. E. Fisher. 1984. The future of reclamation planning on the Northern Great Plains. In: Proc. Third Biennial Symp. on Surface Coal Mine Reclamation on the Great Plains. Billings, MT, p. 102-110.

Murphy, P. M. (compiler). 1983. The challenge of producing native plants for the intermountain area. Proc.: Intermountain Nurseryman's Assoc. 1983 Conf. U.S. For. Serv. Intmt. For. and Rge. Exp. Sta., Gen. Tech. Rep. INT-168, Ogden, UT.

National Academy of Sciences. 1974. Rehabilitation potential of western coal lands. Ballinger Publishing Co., Cambridge, MA.

New Mexico, State of. 1972 (Revised 1979). New Mexico Surface Mining Act. Chapter 291.

New Mexico Coal Surface Mining Commission. 1980, Revised 1984. State of New Mexico surface coal mining regulations. Rule 80-1. Amendment No. 6.

Nicholas, P. J. and W. J. McGinnies. 1982. An evaluation of 17 grasses and 2 legumes for revegetation of soil and spoil on a coal strip mine. J. of Range Manage. 35(3):288-293.

North Dakota Public Service Commission (NDPSC). 1980 (Revised 1983). Rules governing the reclamation of surface-mined land.

North Dakota Public Service Commission (NDPSC). 1970 (Revised 1983). Laws governing the surface mining and reclamation operations.

Office of Technology Assessment (OTA). 1984. Environmental protection in the federal coal leasing program. OTA-E-237. Washington, D.C.

Orr, H. K. 1977. Re-establishment of wooded waterways and associated upland shrub communities in surface coal mining areas of the northwestern Great Plains. In: Fifth Symp., Surface Mining and Reclamation, NCA/BCR, Coal Conference and Expo. IV; Oct. 18-20, Louisville, KY.

Packer, P. E. 1974. Rehabilitation potentials and limitations of surface-mined land in the Northern Great Plains. U.S. For. Serv. Gen. Tech. Rep. INT-14. Intermt. For. and Rge. Exp. Sta., Ogden, UT.

Packer, P. E., C. E. Jensen, E. L. Noble, and J. A. Marshall. 1982. Models to estimate revegetation potentials of land surface mined for coal in the west. U.S. For. Serv. Gen. Tech. Rep. INT-123. Intermt. For and Rge. Exp. Sta., Ogden, UT.

Pavlichek, K. A., G. V. Johnson, and E. F. Aldon. 1977. Vegetative propagation of desert saltgrass rhizomes. Journal of Range Manage. 30(5): 377-380.

Peet, R. K. 1974. The measurement of species diversity. Annu. Rev. Ecol. Syst. 5:285-307.

Phillips, C. M. and W. A. Berg. 1976. Establishment of native shrubs on disturbed lands in the mountain shrub vegetation type. Colo. St. Univ. Agron. Dept., Disturbed Lands Res., Fort Collins, CO.

Pielou, E. C. 1976. The measurement of diversity in different types of biological collections. J. Theor. Biol. 13: 131-144.

Pielou, E. C. 1975. Ecological diversity. New York: John Wiley and Sons.

Pielou, E. C. 1974. Population and community ecology. Principles and methods. New York: Gordon and Breach Science Publishers.

Power, J. F., R. F. Ries, and F. M. Sandoval. 1978. Reclamation of coal-mined lands in the Northern Great Plains. J. of Soil and Water Conservation 33(2):69-74.

Proctor, B., R. Thompson, J. Bunin, K. Fucik, G. Tamm, and E. G. Wolf. 1983a. Practices for protecting and enhancing fish and wildlife on coal surface-mined land in the Green River-Hams Fork region. U.S. Fish and Wildl. Serv. FWS/OBS-83/09.

Proctor, B., R. Thompson, J. Bunin, K. Fucik, G. Tamm, and E. G. Wolf. 1983b. Practices for protecting and enhancing fish and wildlife on coal surface-mined land in the Powder River-Ft. Union region. U.S. Fish and Wildl. Serv. FWS/OBS-83/10.

Prodgers, R. A. 1983. Review, evaluation and recommendations for premine vegetation inventories in Montana, Wyoming, Colorado and North Dakota. In: Coal Development: Collected Papers, Volume Two. S. Fisher (proj. coord.), Bureau of Land Management.

Public Law 95-87. Surface Mining Control and Reclamation Act. 95th Congress.

Rauzi, F. and G. E. Schuman. 1982. Fertilization of four grasses established on topsoiled and nontopsoiled mined land. U.S. Agr. Res. Serv. Agr. Res. Results. ARR-W-24.

Reclamation Research Advisory Committee and North Dakota Public Service Commission. 1984. A report on reclamation research in North Dakota: Inventory of past and ongoing research and identification of future research needs. Prepared for the North Dakota Legislative Council, Bismarck, ND.

Redente, E. F. and C. W. Cook. 1984. Ecological studies of natural and established ecosystems on energy related disturbances in Colorado. Colo., St. Univ. Res. Rep., U.S. Dept. of Energy, DOE/EV/4018-7, Fort Collins, CO.

Redente, E. F., W. E. Sowards, D. G. Steward, T. L. Ruiter (eds.). 1983. Western reclamation group symposium on western coal mining regulatory issues: land use, revegetation, and management. Colo. St. Univ. Rge. Sci. Dept., Sci. Ser. No. 35, Fort Collins, CO.

Reeves, F. B., J. Acsai, S. Solhaibani, and A. Park. 1984. Importance of mycorrhizal fungi in revegetating disturbed soils and retorted shale. In: Ecological studies of natural and established ecosystems on energy related disturbances in Colorado. Redente, E. F. and C. W. Cook (eds.), U.S. Dept. of Energy, DOE/EV/04018-7.

Richardson, B. Z. and E. E. Farmer. 1982. Changes in sodium adsorption ratios following revegetation of coal mine spoils in southestern Montana. U.S. For. Ser. Res. Paper INT-287, Intermt. For. and Rge. Exp. Sta., Ogden, UT.

Ries, R. 1982. Warm season grasses for revegetation in the Northern Great Plains. In: Symposium on Surface Coal Mining and Reclamation in the Northern Great Plains. Mont. Agr. Exp. Sta., Res. Rep. No. 194.

Ries, R. E. and L. Hoffman. 1984. Pasture and hayland: measures of reclamation success. In: Proc. Third Biennial Symp. on Surface Coal Mine Reclamation on the Great Plains, Billings, MT, p. 307-317.

Ries, R. E. and L. Hofmann. 1983. Re-establishment and use of grasslands on reclaimed soils. In Can Mined Lands Be Made Better Than Before Mining?, pp. 85-93, Stronghold Press, Bismarck, ND.

Ries, R. E., L.Hoffman, and W. C. Whitman. 1980. Potential control and value of seeds in prairie hay for revegetation. Reclamation Rev. 3:149-160.

Ries, R. E. and E. J. DePuit. 1984. Perennial grasses for mined land. J. of Soil and Water Conservation 39(1).

Schaller, F. W. and P. Sutton (eds.). 1978. Reclamation of drastically disturbed lands. Am. Soc. Agron., Madison, WI.

Schuman, G. E. 1982. Forage quality of several grass species grown on reclaimed mined lands. In: Proc. Trace Element Mobilization in Western Energy Regions. Gough, L. P. and R. C. Severson (eds.).

Schuman, G. E., D. T. Booth, J. W. Waggoner, and F. Rauzi. 1984. The effect of grazing reclaimed mined lands on forage production and composition. Second Intl. Rangeland Congress., Adelaide, Australia.

Schuman, G. E., F. F. Munshower, R. E. Ries, and E. G. Robbins. 1980. Quality and heavy metal content of forages grown on reclaimed mined lands in the northern great plains. Univ. of Wyo. Agr. Exp. Sta., RJ 159, GPAC 98, Laramie, WY.

Schuman, G. E. and J. F. Power. 1980. Plant growth as affected by topsoil depth and quality on mined lands. In: Adequate Reclamation of Mined Lands? Symp. Proc., SCS and WRCC-21, Billings, MT.

Schuman, G. E., E. M. Taylor, Jr., F. Rauzi, and G. S. Howard. 1980. Standing stubble versus crimped straw mulch for establishing grass on mined lands. J. of Soil and Water Conservation, 35(1):25-27.

Severson, K. E. and C. E. Boldt. 1977. Problems associated with management of native woody plants in the western Dakotas. In: Proc. of the Sixth Wyo. Shrub Ecology Workshop. K. L. Johnson (ed.).

Shatton, D. 1985. Acting State Conservationist, USDA SCS, Mandan, ND, pers. comm.

Shaw, N. and S. B. Monsen. 1983. Nursery propagation and outplanting of bareroot chenopod seedlings. In: Proc. - Symp. on the Biology of Atriplex and Related Chenopods. A. R. Tiedemann, E. D. McArthur, H. C. Stutz, R. Stevens, and K. L. Johnson (compilers). U.S. For. Serv., Intmt. For. and Rge. Exp. Sta., Gen. Tech. Rep. INT-172, Ogden, UT.

Shelford, V. E. 1974. The ecology of North America. Univ. of Ill. Press.

Sherman, R. M., and E. F. Sullivan. 1980. Irrigation for reclamation of strip mined lands. Bur. of Mines Open File Doc. Rep. 12-82.

Sims, P. L., J. S. Singh, and W. K. Laurenroth. 1978. The structure and function of ten western North American grasslands. Part I. Abiotic and vegetational characteristics. J. of Ecol. 66:251-185.

Sindelar, B. W. 1973. Dryland sodding with native grasses for permanent erosion control. Mont. Agr. Exp. Sta. Res. Rep. No. 43, Bozeman, MT.

Singh, J. S., W. K. Lauenroth, and R. K. Steinhorst. 1975. Review and assessment of various techniques for estimating net aerial primary production in grasslands from harvest data. The Botanical Review 41(2):181-231.

Smith, J. A., G. E. Schuman, E. J. DePuit, and T. A. Sedbrook. 1984. Establishment and production of forages on wood residue amended bentonite mine spoils. Soc. for Range Manage. Abstract No. 283.

Smith, J. A., G. E. Schuman, E. J. DePuit, and T. A. Sedbrook. 1983. Effectiveness of wood residue as a soil amendment for reclamation of bentonite mine spoils. Soc. for Range Manage. Abstract No. 245.

Society for Range Management. 1974. A glossary of terms used in range management. 2nd ed. M. M. Kotham, ed., Denver, CO, Belke Printing.

Sowards, W. E. 1983. Achieving an adequate sample size for vegetation analyses. In: Western Reclamation Group Symp. on Western Coal Mining Regulatory Issues: Land Use, Revegetation and Management. E. F. Redente, W. E. Sowards, D. G. Steward, and T. L. Ruiter (eds.). Colo. St. Univ. Rge. Sci. Dept. Science Ser. No. 35, Fort Collins, CO.

Sprackling, J. A. 1977. Early field survival of bare-root, container-grown, and potted ponderosa pine seedlings in south-central Nebraska. U.S. For. Serv. Res. Note RM-335, Rocky Mt. For.and Rge. Exp. Sta., Fort Collins, CO.

Stanley, M. A., G. E. Schuman, F. Rauzi, and L. I. Painter. 1982. Quality and element content of forages grown on three reclaimed mine sites in Wyoming and Montana. Reclamation and Revegetation Research 1:311-326.

Stark, N. 1982. The soils and ecology of establishing ponderosa pines on reclaimed lands. In: Symp. on Surface Coal Mining and Reclamation in the Northern Great Plains, Billings, MT, Mont. Agr. Exp. Sta. Res. Rep. No. 194.

States, J. B., P. T. Haug, T. G. Shoemaker, L. Reed, and E. Reed. 1978. A systems approach to ecological baseline studies. U.S. Fish and Wildl. Serv., FWS/OBS-78/21.

Stelter, L. H., E. J. DePuit, and S. A. Mikol (tech. coordinators). 1981. Shrub establishment on disturbed arid and semi-arid lands. Wyoming Game and Fish Dept., Cheyenne, WY.

Steward, D. G. 1983. Using a similarity index to evaluate revegetation success. In: Western Reclamation Group Symp. on Western Coal Mining Issues: Land Use, Revegetation and Management. E. F. Redente, W. E. Sowards, D. G. Steward, and T. L. Ruiter (eds.). Colo. St. Univ. Rge. Sci. Dept., Sci. Ser. No. 35, Fort Collins, CO.

Stutz, H. C. 1982. Atriplex hybridization in western North America. In: Proc. - Symp. on the Biology of Atriplex and Related Chenopods. Tiedemann, A. R., E. D. McArthur, H. C. Stutz, R. Stevens, and K. L. Johnson (compilers). U.S. For. Ser. Intermt. For. and Rge. Exp. Sta., Gen. Tech. Rep. INT-172, Ogden, UT.

Stutz, H. C. 1982. Breeding superior plants for disturbed lands. Paper presented at western mined-land rehabilitation research workshop. U.S. For. Serv., Fort Collins, CO.

Stutz, H. C. 1982. Broad gene pools required for disturbed lands. In: Reclamation of mined lands in the southwest. A symp. E. F. Aldon and W. R. Oaks (eds.). SCS, Albuquerque, NM.

Thornburg, A. A. 1982. Plant materials for use on surface mined lands in arid and semi-arid regions. USDA SCS-TP-157, EPA-600/7-79-134.

Tiedemann, A. R., E. D. McArthur, H. C. Stutz, R. Steens, and K. L. Johnson (compilers). 1983. Proc. - Symp. on the Biology of Atriplex and Related Chenopods. U.S. For. Serv., Internal For. and Rge. Exp. Sta., Gen. Tech. Rep. INT-172, Ogden, UT.

U.S.D.A. Agricultural Research Service and Colorado State University. 1975. Ecological responses of native plants and guidelines for management of shortgrass range. Technical Bulletin 1503, Washington, D.C.

U.S. Forest Service (USFS). 1968. Range environmental analysis, Rocky Mountain Region. Handbook 2209.21.

U.S. Soil Conservation Service (SCS). 1976. National Range Handbook NRH-1, Washington, D.C.

U.S.Bureau of Land Management (BLM). 1979. Manual 4412 - Physical resource studies. Section 4412.14 - Soil-vegetation inventory method. Washington, D.C.

U.S. Office of Surface Mining (OSM). 1979. Surface coal mining and reclamation operations: permanent regulatory program. Federal Register Vol. 44, No. 50, 3-13-79. Book 3: pp. 15311-15463.

U.S. Forest Service (USFS). 1984. Vegetative rehabilitation and equipment workshop. 38th Annual Report. Equipment Development Center, Rapid City, SD.

U.S. Forest Service (USFS). 1979. User guide to vegetation. Gen. Tech. Rep. INT-64, Intermt. For. and Rge. Exp. Sta., Ogden, UT.

Utah State University. In press. Proc. of a symp. on crested wheatgrass. Utah St. Univ., Rge. Sci. Dept., Logan, UT.

Vallentine, J. F. 1980. Range developments and improvements, 2nd ed. Brigham Young Univ. Press, Provo, UT.

VanDyne, G. M. 1984. Evluation of available vegetation data and sampling procedures for pre- and post-mining vegetation assessments in North Dakota. Part I: Ecological and sampling considerations in the rehabilitation of surface-mined lands. Reclamation Research Advisory Committee and North Dakota Public Service Commission.

VanDyne, G. M. and R. L. Hollingsworth II. 1984. Evluation of available vegetation data and smapling procedures for pre- and post-mining vegetation assessments in North Dakota. Part II: Yield and composition of vegetation on North Dakota soil series and rangeland sites. Reclamation Research Advisory Committee and North Dakota Public Service Commission.

VanDyne, G. M. and D. M. VanDyne. 1984. Evluation of available vegetation data and smapling procedures for pre- and post-mining vegetation assessments in North Dakota. Part III: Measurement of standing crop dynamics and production of western North Dakota plant communities. Reclamation Research Advisory Committee and North Dakota Public Service Commission.

VanDyne, G. M. and M. K. Wali. 1984. Evaluation of available vegetation data and sampling procedures for the development of guidelines for pre- and post-mining vegetation assessments in North Dakota. Part I: Ecological and sampling considerations in the rehabilitation of surface-mined lands. Reclamation Research Advisory Committee and North Dakota Public Serv. Commission.

VanEpps, G. A. and C. M. McKell. 1980. Revegetation of disturbed sites in the salt desert range of the intermountain west. Utah Agr. Exp. Sta. Land Rehab. Series No. 5. College of Nat. Res. Utah St. Univ., Logan, UT.

VanEpps, G. A. and C. M. McKell. 1978. Major criteria and procedures for selecting and establishing range shrubs as rehabilitators of disturbed lands. Proc. First International Rangeland Congress.

Vories, K. C. and P. L. Sims. 1977. The plant information network. Vol. III - Reclamation and PIN in the Powder River Basin of Montana and Wyoming. U.S. Fish and Wildl. Serv. FWS/OBS-77/40.

Wali, M. K. (ed.). 1982 to current, published quarterly. Reclamation and revegetation research. Elsevier Publishing Co., Amsterdam.

Walsh, J. P. and Assoc. 1985. Soil and overburden management in western surface coal mine reclamation. Prepared for OTA.

Wells, R. W. 1965. Scarp woodlands, transported grassland soils, and concept of grassland climate in the great plains region. Science 162: 246-249.

Western Water Consultants, Inc. 1985. Hydrologic technologies for western surface coal mining. Prepared for OTA.

White, S. M., W. K. Ostler, and C. McKell. 1982. Coal refuse - an increasingly serious problem for Colorado plateau coal production. U.S. Dept. of Energy, Div. of Coal Mining. FE-24.

Whittaker, R. H. 1972. Evolution and measurement of species diversity. Taxon. 21(2/3):213-251.

Williams, S. E. and E. F. Aldon. 1976. Endomycorrhial (vesicular arbuscular) associations of some arid zone shrubs. The Southwestern Naturalist 20(4):437-444.

Williams, S. E. and M. F. Allen (eds.). 1982. VA mycorrhizae and reclamation of arid and semi-arid lands. Proc. of the Conf. Dubois, Wyoming. Trail Lake Ranch. Aug. 17-19, 1982. Wyo. Agr. Exp. Sta. Rep. No. SA1261, Laramie, WY.

Williamson, R. L. 1984. Re-establishing North Dakota grasslands after mining with emphasis on seasonality and use of native species. J. of Soil and Water Conservation, 39(6):387-391.

Wright, R. A. (ed.). 1977. The reclamation of disturbed arid lands. Univ. of New Mexico Press, Albuquerque, NM.

Wyoming Department of Environmental Quality (WDEQ). 1984. Addenum to rules and regulations. Land Quality Division, Cheyenne, WY.

Wyoming Department of Environmental Quality (WDEQ). 1981 (Revised 1984). Land Quality Division Guideline No. 2, Vegetation, Cheyenne, WY.

Wyoming Department of Environmental Quality (WDEQ). 1980 (Revised 1983.) Rules and regulations. Land Quality Division, Cheyenne, WY.

Wyoming, State of. 1973 (Revised 1982). Wyoming Environmental Quality Act.

Wyoming Game and Fish Department (WGF). 1981. Shrub establishment on disturbed arid and semi-arid lands, Cheyenne, WY.

Yamamoto, T. 1975. Coal mine spoil as a growing medium: AMAX Belle Ayr South Mine, Gillette, WY. p. 49-61 In: Third Symp. on Surf. Min. and Reclam., Vol. 1. NCA/BCR Coal Conf. and Expo II. Natl. Coal Assoc., Washington, D.C.

Young, J. A., R. A. Evans, B. L. Kay, R. E. Owen, and J. Budy. 1981. Collecting, processing, and germinating seeds of western wildland plants. U.S.D.A. Sci. and Ed. Admin., Agricultural Reviews and Manuals. ARM-W-3, Oakland, CA.

Young, S. A. 1982. Establishment of native species on revegetated mine soils following supplemental irrigation. In: Symp. on Surface Coal Mining and Reclamation in the Northern Great Plains, Billings, MT. Mont. Agr. Exp. Sta., Res. Rep. No. 194.

APPENDIX A

GROUPS AND INDIVIDUALS CONTACTED

APPENDIX A
GROUPS AND INDIVIDUALS CONTACTED

FEDERAL REGULATORY AND LAND MANAGEMENT AGENCIES

Bureau of Land Management
James Hagihara, Natural Resource Specialist
D-470, Building 50
Denver Federal Center
Denver, CO 80225

Rhio Jackson, Oil Shale Leasing Specialist
2020 Arapahoe
Denver, CO 80205

USDI, Office of Surface Mining
Arlo Dalrymple
1951 Constitution Avenue N.W.
Washington, DC 20240

Allen Kline, Scott E. Fisher, Jr., and Erven Barchenger
1020 15th Street
Brooks Towers
Denver, CO 80202

STATE REGULATORY AGENCIES

Colorado Natural Resources Department
Sandra Brown, Dan Matthews, and Mike Savage
Mined Land Reclamation Division
423 Centennial Building
1313 Sherman Street
Denver, CO 80203-2273

Montana Department of State Lands
Sandra Olsen, Terry Conway, and Steve Regele
Capitol Station
Helena, MT 59601

New Mexico Energy and Minerals Department
Bob Edger
Mining and Minerals Division
525 Camino de los Marquez
Santa Fe, NM 87501

North Dakota Public Service Commission
Ed Englerth, Jim Deutsch, Nirander Safaya, and Lou Ogaard
Reclamation Division
State Capitol Building, 13th Floor
Bismarck, ND 58501

Wyoming Department of Environmental Quality
Paige Waldvogel and Jack Smith, Plant Ecologists
Steve Tessman, Wildlife Specialist
Land Quality Division
Herschler Building - Third Floor
122 West 25th Street
Cheyenne, WY 82002

Bob Giurgevich
Land Quality Division
30 East Grinnell Street
Sheridan, WY 82801

MINING COMPANIES

AMAX Coal Company
Mickey Steward, Reclamation Coordinator
P.O. Box 3005
Gillette, WY 82716

Arch Mineral Corporation
David C. Porterfield, Environmental Specialist
P. O. Box 490
Hanna, WY 82327

Black Butte Mine
Scott Kamber, Environmental Supervisor
P. O. Box 98
Point of Rocks, WY 82942

Bridger Coal Company
Fred Parady, Reclamation Specialist
P. O. Box 2068
Rock Springs, WY 82901

Carter Mining Company
Dennis McGirr, Reclamation Coordinator
P. O. Box 3007
Gillette, WY 82716

ColoWyo Coal Company
Rich Adkinson
5731 State Highway 13
Meeker, CO 81641

Consolidation Coal Company
Dave Nilson and Jim Thompson
Glenharold Mine
Stanton, ND 58571

Energy Fuels Corporation
Dave Gossett, Chief Mining Engineer
P. O. Box 773457
Steamboat Springs, CO 80477

Getty Mining Company
Ken Crofts and Clem Parkin, Reclamation and Range Scientists
23385 Routt County Road 33
Oak Creek, CO 80467

Glenrock Coal Company
Chet Skilbred, Reclamation Specialist
Dave Johnston Mine
Glenrock, WY

Knife River Coal Company
Dale Mormon, Reclamation Coordinator
1950 North Kavaney Drive
Bismarck, ND 58501

North American Coal Company
Randy Crook, Reclamation Coordinator
Fallkirk Mine
2000 Schafer Street
Bismarck, ND 58501

Peabody Coal Company
Vern Pfannenstiel
10375 East Harvard Avenue
Suite 400
Denver, CO 80231

Sunedco Coal Company
Jim Sutherland, Reclamation Specialist
Cordero Mine
P. O. Box 1449
Gillette, WY 82716

Trapper Mining, Inc.
Bruce Humphries, Senior Environmental Engineer
P. O. Box 187
Craig, CO 81626

Thunder Basin Coal Company
Kim Carroll, Environmental Supervisor
P. O. Box 406
Wright, WY 82732

Utah International
Walt Ruzzo, Reclamation Specialist
Navajo Mine
P.O. Box 155
Fruitland, NM 87416

Western Energy Company
Joe Coenenberg and Bill Schwarzkopf
Rosebud Mine
Colstrip, MT 59323

Westmoreland Coal Company
Michelle Mitchell, Environmental Coordinator
Absaloka Mine
Box 449
Hardin, MT 59034

ENVIRONMENTAL GROUPS

Colorado Open Space Council
Mark Welsh
2239 East Colfax Avenue
Denver, CO 80206

Environmental Defense Fund
Bob Yuhnke
1405 Arapahoe
Boulder, CO 80302

Dakota Research Council
Theresa Keaveny
29 7th Avenue West
Dickinson, ND 58601
Friends of the Earth
Connie Albrecht
P. O. Box 728
Palisade, CO 81526

National Wildlife Federation
Kelly Green
Natural Resources Clinic
Fleming Law Building
University of Colorado
Boulder, CO 80309

Natural Resources Defense Council
Laura King
240 Kearney Street
San Francisco, CA 94108

Northern Plains Resource Council
John Smillie
419 Stapleton Building
Billings, MT 59101

Powder River Basin Resource Council
Jim Flaherty
48 North Main
Sheridan,WY 82801

Sierra Club Southwest
Maggie Fox
727 Walnut Street
Boulder, CO 80302

Jonathan Teague
P. O. Box 4524
Albuquerque, NM 87106

Western Organization of Resource Councils
Pat Sweeney
P. O. Box 1742
Montrose, CO

FEDERAL RESEARCH AGENCIES

USDA, Agricultural Research Service
Gerry Schuman, Research Leader
High Plains Grassland Research Station
8408 Hildreth Road
Cheyenne, WY 82009

Steve Merrill and Len Hofman
Northern Great Plains Research Center
P. O. Box 459
Mandan, ND 58554

USDA, Soil Conservation Service
Sam Stranathan, Manager
Upper Colorado Environmental Plant Center
P. O. Box 448
Meeker, CO 81641

Don Fulton, Range Conservationist
West National Technical Center
511 N.W. Broadway, Room 547
Portland, OR 91209-3489

Carter Steers
Information Resource Management Staff
Southern National Technical Center
P. O. Box 6567
Fort Worth, TX 76115

Mark Mazeras
Plant Materials Center
P. O. Box 81, Route 1
Bridger, MT 59014

Russ Hawes
Plant Materials Center
P. O. Box 1458
Bismarck, ND 58501

USDA, Forest Service

Durant McArthur
Intermountain Forest and Range Experiment Station
Shrub Sciences Lab
735 North 500 East
Provo, UT 84601

Ray Brown and Eugene Farmer
Intermountain Forest and Range Experiment Station
Forestry Sciences Lab
Logan, UT 84321

Richard Hallman
Missoula Equipment Development Center
Missoula, MT 59801

Earl Aldon, Project Leader
Rocky Mountain Forest and Range Experiment Station
2205 Columbia S.E.
Albuquerque, NM 87106

Ardell Bjugstad
Rocky Mountain Forest and Range Experiment Station
Forest Research Lab
South Dakota School of Mines and Technology
Rapid City, SD 57701

UNIVERSITY AND PRIVATE RESEARCH GROUPS

Argonne National Laboratory

Ray Hinchman, Biologist
9700 South Cass Avenue
Argonne, IL 60439

Brigham Young University

Howard Stutz
Department of Botany and Range Science
Provo, UT 84601

Colorado State University
Edward Redente
Department of Range Science
Fort Collins, CO 80523

Montana State University
Frank Munshower
Reclamation Research Unit
Bozeman, MT 59717

Native Plants, Inc.
Cyrus McKell
360 Wakara Way
University Research Park
Salt Lake City, UT 84108

North Dakota State University
Gene Doll, Nyle Wollenhaupt, Gary Halvorson
Land Reclamation Research Center
P. O. Box 459
Mandan, ND 58554

University of Montana
Nellie Stark
Forestry Department
Missoula, MT

University of Wyoming
Ed DePuit
College of Agriculture
Range Management Department
P. O. Box 3354, University Station
Laramie, WY 82071

Utah State University
Edie Allen and Jim Richards, Codirectors
Institute for Land Rehabilitation
Logan, UT 84321

APPENDIX B

SEED MIXES

APPENDIX B

SEED MIXES

MINE CO-1

Rangeland Mixture

Species	Common Name	PLS lbs/acre
Bromus marginatus	Mountain Brome	1.53
Agropyron trachycaulum	Slender Wheatgrass	1.40
Agropyron intermedium	Intermediate Wheatgrass	0.19
Agropyron dasystachyum	Critana Thickspike Wheatgrass	0.72
Agropyron riparium	Sodar Streambank Wheatgrass	0.92
Agropyron desertorum	Nordan Desert Wheatgrass	0.10
Elymus cinereus	Great Basin Wildrye	0.34
Dactylis glomerata	Orchardgrass	0.06
Agropyron smithii	Western Wheatgrass	0.26
Phleum pratense	Timothy	0.02
Agropyron inerme	Whitmar Beardless Wheatgrass	0.38
Poa ampla	Sherman Big Bluegrass	0.32
Stipa viridula	Green Needlegrass	0.16
Bromus biebersteinii	Regar Medow Brome	0.20
Medicago sativa	Alfalfa	0.21
Astragalus cicer	Lutana Cicer Milkvetch	0.24
Linus lewisii	Lewis Flax	0.10
Sanguisorba minor	Small Burnet	0.22
Balsamorhiza sagittata	Arrowleaf Balsamroot	0.17
Penstemon strictus	Rocky Mountain Penstemon	0.18
Aster glaucodes	Smooth Aster	0.02
Helianthus annuus	Sunflower	0.11
Osmorhiza occidentalis	Sweetanise	0.18
Achillea millefolium	Western Yarrow	0.08
Artemisia tridentata ssp. vaseyana	Mountain Big Sagebrush	0.81
Purshia tridentata	Antelope Bitterbrush	0.76
Chrysothamnus nauseosus	Rubber Rabbitbrush	0.03
Chrysothamnus viscidiflorus	Yellow Rabbitbrush	0.03
Amelanchier alnifolia	Saskatoon Serviceberry	0.76
Prunus virginiana var. melanocarpa	Black Chokecherry	0.73
Rosa woodsii	Woods' Rose	0.76
	Total	12.0

Pastureland Mixture

Species	Common Name	PLS lbs/acre
Agropyron trachycaulum	Slender Wheatgrass	2.0
Agroypron intermedium	Intermediate Wheatgrass	2.0
Agropyron trichophorum	Pubescent Wheatgrass	2.0
Agropyron desertorum	Desert Wheatgrass	1.5
Dactylis glomerata	Orchardgrass	0.5
Phleum pratense	Timothy	0.5
Bromus biebersteinii	Regar Meadow Brome	1.0
Bromus inermis	Lincoln Smooth Brome	2.0
Medicago sativa	Alfalfa	0.25
Astragalus cicer	Cicer Milkvetch	0.25
	Total	12.0

Cropland Mixture

Species	Common Name	PLS lbs/acre
Bromus biebersteinii	Regar Meadow Brome	3
Agropyron intermedium	Intermediate Wheatgrass	3
Dactylis glomerata	Orchardgrass	2
Phleum pratense	Timothy	2
Medicago sativa	Alfalfa - Ladak	2
	Total	12.0

MINE CO-2

Basic Mixture

Species	Common Name	PLS lbs/acre
Agropyron trachycaulum	Slender Wheatgrass	0.19
Agropyron trichophorum	Pubescent Wheatgrass	0.19
Elymus junceus	Russian Wildrye	0.18
Agropyron inerme	Beardless Wheatgrass	0.38
Agropyron smithii	Western Wheatgrass	0.26
Agropyron riparium	Streambank Wheatgrass	0.20
Agropyron desertorum	Desert Wheatgrass	0.21
Oryzopsis hymenoides	Indian Ricegrass	0.27
Stipa viridula	Green Needlegrass	0.14
Sitanion hystrix	Bottlebrush Squirreltail	0.11
Agropyron elongatum	Tall Wheatgrass	0.20
Poa ampla	Big Bluegrass	0.16
Agropyron dasystachyum	Thickspike Wheatgrass	0.65
Penstemon strictus	Rocky Mountain Penstemon	0.34
Linum lewisii	Lewis Flax	0.47
Sanguisorba minor	Small Burnet	0.57
Astragalus cicer	Cicer Milkvetch	0.42
Hedysarum boreale	Utah Sweetvetch	0.42
Achillea millefolium	Western Yarrow	0.23
Aster chilensis	Pacific Aster	0.06
Artemisia tridentata ssp. wyomingensis	Wyoming Big Sagebrush	2.42
Chrysothamnus nauseosus	Rubber Rabbitbrush	1.76
Purshia tridentata	Antelope Bitterbrush	2.30
Ceratoides lanata	Winterfat	2.13
	Total	14.0

MINE MT-1

Uplands Cool-Season Grass Mixture

Species	Common Name	PLS lbs/acre
Agropyron smithii	Rosana Western Wheatgrass	8
Agropyron dasystachyum	Critana Thickspike Wheatgrass	5
Stipa viridula	Green Needlegrass	6
Agropyron trachycaulum	Slender Wheatgrass	1

The following warm-season grass species will be "patch seeded" on selected postmine sites of one acre or less in this management unit to simulate natural warm-season grass communities.

Andropogon gerardii	Big Bluestem)	
Andropogon hallii	Sand Bluestem)	
Schizachyrium scoparium	Little Bluestem)	40
Calamovilfa longifolia	Prairie Sandreed)	
	Total	60

Steep Uplands Cool-Season Grass Mixture

Species	Common Name	PLS lbs/acre
Agropyron smithii	Rosana Western Wheatgrass	3
Stipa viridula	Green Needlegrass	10
Agropyron dasystachyum	Critana Thickspike Wheatgrass	6
Agropyron trachycaulum	Slender Wheatgrass	1

The following warm-season grass species will be "patch seeded" on selected postmine sites of one acre or less in this management unit to simulate natural warm-season grass communities.

Andropogon gerardii	Big Bluestem)	
Andropogon hallii	Sand Bluestem)	
Schizachyrium scoparium	Little Bluestem)	40
Calamovilfa longifolia	Prairie Sandreed)	
	Total	60

Lowland/Drainage Mixture

Species	Common Name	PLS lbs/acre
Agropyron smithii	Rosana Western Wheatgrass	6
Agropyron trachycaulum	Slender Wheatgrass	4
Agropyron dasystachyum	Critana Thickspike Wheatgrass	2
Bromus marginatus	Mountain Brome	2
Poa pratensis	Kentucky Bluegrass	2
Poa compressa	Canada Bluegrass	2
Elymus canadensis	Canada Wildrye	2
	Total	20

Wetland/Riparian Mixture

Species	Common Name	PLS lbs/acre
Panicum virgatum	Switchgrass	10
Spartina pectinata	Prairie Cordgrass	6
Poa juncifolia	Alkali Bluegrass	2
Carex spp.	Wetland Sedges	2
	Total	20

Conifer Zone Grass Mixture

Species	Common Name	PLS lbs/acre
Stipa viridula	Green Needlegrass	8
Bouteloua curtipendula	Sideoats Grama	8
Oryzopsis hymenoides	Indian Ricegrass	2
Agropyron smithii	Rosana Western Wheatgrass	1
Agropyron dasystachyum	Critana Thickspike Wheatgrass	1

The following warm-season grass species will be "patch seeded" on selected postmine sites of one acre or less in this management unit to simulate natural warm-season grass communities.

Species	Common Name	PLS lbs/acre
Andropogon gerardii	Big Bluestem	40
Andropogon hallii	Sand Bluestem	
Schizachyrium scoparium	Little Bluestem	
Calamovilfa longifolia	Prairie Sandreed	
	Total	60

Supplemental Grass, Forb, and Shrub Mixture*

Species	Common Name	PLS lbs/acre
Bouteloua curtipendula	Sideoats Grama	3.6
Stipa comata	Needle-and-thread	2
Oryzopsis hymenoides	Indian Ricegrass	1.3
Atriplex canescens	Fourwing Saltbush	0.7
Ceratoides lanata	Winterfat	1.3
Bouteloua gracilis	Blue Grama	1.3
Linum lewisii	Lewis Flax	0.7
Ratibida columnifera	Prairie Coneflower	0.7
Achillea millefolium lanulosa	Western Yarrow	0.7
Petalostemon purpureum	Purple Prairie-Clover	
P. candidum	White Prairie-Clover	
Astragalus cicer	Cicer Milkvetch (Lutana)	
Onobrychis viciefolia	Sainfoin (ESKE)	

*Wintergraze or barley is included as a temporary cover crop with the supplemental mix.

Indigenous Trees and Shrubs for Revegetation*

Species	Common Name	Management Unit Mix
Acer negundo	Box-elder	Wetland/Riparian; Lowland/Drainage
Artemisia cana	Silver Sagebrush	Lowland/Drainage; Uplands; Steep Uplands Conifer Zone
Artemisia tridentata	Big Sagebrush	Uplands; Steep Uplands; Conifer Zone
Chrysothamnus nauseosus	Rubber Rabbitbrush	Uplands; Steep Uplands; Conifer Zone
Chrysothamnus viscidiflorus	Green Rabbitbrush	Uplands; Steep Uplands; Conifer Zone
Crataegus succulenta	Fleshy Hawthorn	Wetland/Riparian; Lowland/Drainage
Fraxinus pennsylvanica	Green Ash	Wetland/Riparian; Lowland/Drainage
Juniperus scopulorum	Rocky Mountain Juniper	Lowland/Drainage; Conifer Zone
Pinus ponderosa	Ponderosa Pine	Conifer Zone
Populus angustifolia	Narrowleaf Cottonwood	Wetland/Riparian
Populus deltoides	Plains Cottonwood	Wetland/Riparian
Prunus americana	American Plum	Wetland/Riparian; Lowland/Drainage
Prunus virginiana	Chokecherry	Wetland/Riparian; Lowland/Drainage
Rhus trilobata	Skunkbush Sumac	Uplands; Steep Uplands; Conifer Zone
Ribes aureum	Golden Currant	Wetland/Riparian; Lowland/Drainage
Ribes cereum	Squaw Currant	Wetland/Riparian; Lowland/Drainage

*When not commercially available, seeds from native indigenous stands of these species are collected on an annual basis and sent to a greenhbouse for propagation as containerized plants for use in revegetated areas.

Indigenous Trees and Shrubs for Revegetation (cont.)

Species	Common Name	Management Unit Mix
Ribes setosum	Redshoot Gooseberry	Wetland/Riparian; Lowland/Drainage
Rosa woodsii	Woods' Rose	Wetland/Riparian; Lowland/Drainage
Salix amygdaloides	Peachleaf Willow	Wetland/Riparian
Salix phylicifolia	Tealeaf Willow	Wetland/Riparian
Symphoricarpos occidentalis	Western Snowberry	Lowland/Drainage
Shepherdia argentea	Silver Buffaloberry	Lowland/Drainage
Yucca glauca	Yucca	Uplands; Steep Uplands; Conifer Zone

Indigenous Forbs and Half Shrubs for Revegetation*

Species	Common Name
Achillea millefolium lanulosa	Western Yarrow
Allium textile	Prairie Onion
Argemone intermedia	Prickly Poppy
Asclepias pumila	Plains Milkweed
Astragalus crassicarpus	Groundplum Milkvetch
Astragalus gracilis	Slender Milkvetch
Astragalus missouriensis	Missouri Milkvetch
Atriplex canescens	Fourwing Saltbush
Balsamorhiza sagittata	Arrowleaf Balsamroot
Calochortis nuttallii	Sego (Mariposa) Lily
Campanula rotundifolia	Roundleaf Harebell
Castilleja sessiliflora	Largeflowered Paintbrush
Ceratoides lanata	Winterfat
Cleome serrulata	Rocky Mountain Beeplant
Echinacea pallida	Purple Coneflower
Eriogonum annuum	Annual Eriogonum
Erysimum asperum	Plains Wallflower
Gaillardia aristata	Blanketflower
Gilia congesta	Ballhead Gilia
Helianthus petiolaris	Prairie Sunflower

*When not commercially available, and when practical, seeds from native indigenous stands of the above species are collected on an annual basis. The seeds are sent to a greenhbouse for propagation as containerized plants for use in reclamation.

Indigenous Forbs and Half Shrubs for Revegetation (cont.)

Species	Common Name
Hedysarum boreale	Northern Sweetvetch
Hedysarum sulpherescens	White Sweetvetch
Liatris punctata	Dotted Gayfeather
Linum lewisii (perenne)	Lewis Flax
Lithospermum incisum	Narrowleaf Gromwell
Mentzelia decapetala	Tenpetal Blazingstar
Oenothera caespitosa	Tufted Evening-Primrose
Oenothera serrulata	Shrubby Evening-Primrose
Penstemon albidus	White Penstemon
Petalostemon candidum	White Prairie-Clover
Petalostemon purpureum	Purple Prairie-Clover
Thermopsis rhombifolia	Prairie Goldenpea
Psoralea argophylla	Silverleaf Scurfpea
Ratibida columnifera	Prairie Coneflower
Vicia americana	American Vetch

Croplands will be seeded to alfalfa at 46 PLS lbs/acre for 5 years followed by winter wheat planting for 5 years.

MINE ND-1

Grassland Mixture

Species	Common Name	PLS lbs/acre
Agropyron smithii	Western Wheatgrass	4
Stipa viridula	Green Needlegrass	4
Agropyron trachycaulum	Slender Wheatgrass	0.5
Bouteloua curtipendula	Sideoats Grama	4
Bouteloua gracilis	Blue Grama	2
Calamovilfa longifolia	Prairie Sandreed	1
Sporobolus cryptandrus	Sand Dropseed	0.5
Panicum virgatum	Switchgrass	2
Schizachyrium scoparium	Little Bluestem	2
Medicago sativa	Alfalfa	0.5
Andropogon hallii	Sand Bluestem	1
Andropogon gerardii	Big Bluestem)	1
Sorghastrum nutans	Indian-grass)	
	Total	22.5

Tame Pastureland/Hayfields Mixture

Agropyron cristatum	Crested Wheatgrass	4
Bromopsis inermis	Smooth Brome	3
Agropyron trachycaulum	Slender Wheatgrass	1.5
Elymus junceus	Russian Wildrye	2.5
Medicago sativa	Alfalfa	2
	Total	13

Cropland Mixture

Agropyron elongatum	Tall Wheatgrass	4.5
Agropyron intermedium	Intermediate Wheatgrass	4
Melilotus sp.	Sweet Clover	0.5
Medicago sativa	Alfalfa	3
	Total	12

Woodlands Mixture

Species	Common Name	Plants/acre
Salix spp.	Willow	135
Acer negundo	Boxelder	270
Fraxinus pennsylvanica	Green Ash	810
Populus deltoides	Cottonwood	405
Quercus macrocarpa	Burr Oak	135
Populus tremuloides	Aspen	135
Prunus americana	Native Plum	270
Prunus virginiana	Chokecherry	270
Amelanchier alnifolia	Serviceberry	135
Crataegus rotundifolia	Round-leaved Hawthorn	135

Tall Shrub Mixture

Prunus americana	Native Plum	675
Shepherdia argentea	Silver Buffaloberry	135
Amelanchier alnifolia	Serviceberry	540
Prunus virginiana	Chokecherry	540
Crataegus rotundifolia	Round-leaved Hawthorn	540
Cornus stolonifera	Red Osier Dogwood	135
Ribes setosum	Bristly Gooseberry	135

Low Shrub Mixture

Eleagnus commutata	Silverberry	540
Rosa woodsii	Western Wild Rose	1,080
Symphoricarpos spp.	Snowberry	1,080

MINE NM-1

Basic Mixture

Species	Common Name	PLS lbs/acre
Bouteloua gracilis	Blue Grama	0.5
Oryzopsis hymenoides	Indian Ricegrass	1.0
Hilaria jamesii	Galleta	0.75
Sporobolus airoides	Alkali Sacaton	0.25
Eriogonum spp.	Wildbuckwheat	1.0
Chrysothamnus nauseosus	Rubber Rabbitbrush	0.125
Atriplex confertifolia	Shadscale	0.75
Atriplex obovata	Broadscale	0.75
Sarcobatus vermiculatus	Greasewood	0.25
	Total	5.875

MINE NM-2

Basic Mixture

Species	Common Name	PLS lbs/acre
Hilaria jamesii	Galleta	0.30
Sporobolus airoides	Alkali Sacaton	0.30
Oryzopsis hymenoides	Indian Ricegrass	1.25
Sporobolus cryptandrus	Sand Dropseed	0.10
Bouteloua gracilis	Blue Grama	0.75
Agropyron smithii	Western Wheatgrass	1.0
Atriplex canescens	Fourwing Saltbush	0.50
Atriplex confertifolia	Shadscale	1.25
Eurotia lanata	Winterfat	0.75
	Total	5.2

MINE NM-3

Basic Mixture

Species	Common Name	A PLS/ ft^2	B PLS/ ft^2	C PLS/ ft^2
GRASSES				
Sporobolus airoides	Alkali Sacaton	7.50		
Festuca arizonica	Arizona Fescue			12.5/2.50
Andropogon gerardii	Big Bluestem		2.0	
Bouteloua gracilis	Blue Grama	20.00	15.0	2.00/12.0
Sitanion hystrix	Bottlebrush Squirreltail		0.50	
Hilaria jamesii	Galleta		0.50	
Bouteloua hirsuta	Hairy Grama		0.50	0.50
Koeleria cristata	Junegrass			
Poa pratensis	Kentucky Bluegrass			
Schizachyrium scoparium	Little Bluestem		12.50	2.50
Ceratochloa marginatus	Mountain Brome		1.00	2.50
Stipa comata	Needle-and-thread		0.50	2.50
Sporobolus cryptandrus	Sanddropseed			
Bouteloua curtipendula	Sideoats Grama	5.00	12.00	2.50
Agropyron trachycaulum	Slender Wheatgrass	2.50	0.50	5.0
Muhlenbergia wrightii	Spike Muhly	2.50	1.00	5.0
Agropyron smithii	Western Wheatgrass	12.50	2.50	10.0
Panicum obtusum	Vine Mesquite		1.0	5.0

A = Bottoms Mix
B = Slopes Mix
C = Flats Mix
T = Present in Trace Amounts

Basic Mixture (cont.)

Species	Common Name			
FORBS				
Achillea lanulosa	Western Yarrow	-	T*	T
Artemisia ludoviciana	Louisiana Sage	-	T	T
Liatris punctata	Spotted Gayfeather	-	T	T
Linum lewisii	Lewis Flax	T	T	T
Mirabilis multiflora	Four O'clock	-	T	-
Penstemon barbatus	Firecracker Penstemon	T	T	T
Penstemon strictus	Rocky Mountain Penstemon	T	T	T
Penstemon whippleanus	Whipple Penstemon	-	T	T
Petalostemon purpureum	Purple Prairieclover	T	T	T
Ratibida columnifera	Prairie Coneflower	T	-	T
Sphaeralcea coccinea	Scarlet Globemallow	T	T	T
WOODY PLANTS AND SUCCULENTS				
Artemisia frigida	Fringed Sage	T	T	T
Atriplex canescens	Fourwing Saltbush	T	T	-
Chrysothamnus nauseosus	Rubber Rabbitbrush	T	-	-
Clematis hirsutissima	Western Virgin's Bower	T	T	T
Eurotia lanata	Winterfat	T	T	T
Rhus trilobata	Skunkbush Sumac	-	T	-
Yucca baccata	Spanish Bayonet	-	T	-

MINE WY-1

Grazingland Mixture

Species	Common Name	PLS lbs/acre
Achillea lanulosa	Western Yarrow	0.1
Agropyron dasystachyum or A. inerme	Thickspike Wheatgrass or Beardless Wheatgrass	3.5
Agropyron smithii	Western Wheatgrass	4.0
Agropyron trachycaulum	Slender Wheatgrass	2.5
Artemisia frigida	Fringed Sage	0.5
Bouteloua gracilis	Blue Grama	2.0
Eurotia lanata	Winterfat	1.0
Helianthus sp.	Sunflower	0.5
Stipa viridula	Green Needlegrass	4.0
	Total	18.1

Shrub Phase, Additional Species

		Open		Dense
Artemisia tridentata	Big Sagebrush	0.1	to	3.5
Atriplex canescens	Fourwing Saltbush	0.2	to	1.0
Atriplex gardneri	Gardner's Saltbush	0.2	to	1.0
Chrysothamnus nauseosus	Rubber Rabbitbrush	0.1	to	1.0
	Total	0.6	to	6.5

Bottomland Mixture

Agropyron riparium	Streambank Wheatgrass	3.0
Agropyron smithii	Western Wheatgrass	4.0
Agropyron trachycaulum	Slender Wheatgrass	3.0
Astragalus cicer	Cicer Milkvetch	1.0
Helianthus sp.	Sunflower	0.5
Phalaris arundinacea	Reed Canarygrass	1.0
Poa canbyi	Canby Bluegrass	2.0
Poa pratensis	Bluegrass	2.0
Spartina pectinata	Prairie Cordgrass	1.0
Sporobolus airoides	Alkali Sacaton	1.0
	Total	18.5

Improved Pastureland Mixture

Species	Common Name	PLS lbs/acre
Agropyron smithii	Western Wheatgrass	3.0
Agropyron trichophorum	Pubescent Wheatgrass	6.0
Medicago sativa	Alfalfa	2.0
Melilotus officinalis	Yellow Sweetclover	1.0
Onobrychis viciaefolia	Sainfoin	2.0
Stipa viridula	Green Needlegrass	3.0
	Total	17.0

Alfalfa Hayland Mixture

Species	Common Name	PLS lbs/acre
Bromus inermis	Smooth Brome	4.0
Medicago sativa	Alfalfa	3.0
	Total	7.0

MINE WY-2

Upland Area Mixture

Species	Common Name	PLS lbs/acre
Agropyron dasystachyum	Critana Thickspike Wheatgrass	2.00
Agropyron riparium	Sodar Streambank Wheatgrass	3.00
Agropyron smithii	Rosana Western Wheatgrass	3.00
Agropyron trichophorum	Pubescent Wheatgrass	1.00
Agropyron trachycaulum	Slender Wheatgrass	3.00
Bouteloua gracilis	Blue Grama	1.00
Calamovilfa longifolia	Goshen Prairie Sandreed	3.00
Oryzopsis hymenoides	Paloma Indian Ricegrass	1.00
Stipa viridula	Lodorm Green Needlegrass	0.50
Artemisia tridentata	Big Sagebrush	0.25
	Total	17.75

Drainage Area Mixture

Species	Common Name	PLS lbs/acre
Chrysothamnus viscidiflorus	Green Rabbitbrush	2.00
Artemisia cana	Silver Sagebrush	0.50
Artemisia tridentata	Big Sagebrush	0.50
Petalostemon purpureum	Purple Prairie Clover	0.50
Atriplex canescens	Fourwing Saltbush	0.50
Achillea millefolium	Western Yarrow	0.50
Ceratoides lanata	Winterfat	0.50
	Total	5.0

MINE WY-3

Loamy/Shallow Loamy Mixture

Species	Common Name	PLS lbs/acre
Agropyron dasystachyum	Thickspike Wheatgrass	3
Agropyron riparium	Streambank Wheatgrass	1
Agropyron spicatum	Bluebunch Wheatgrass	2
Agropyron trachycaulum	Slender Wheatgrass	2
Stipa comata	Needle-and-thread	1
Ceratoides lanata	Winterfat	2
Chrysothamnus nauseosus	Rubber Rabbitbrush	2
Lupinus sp.	Lupine	1
Eriogonum spp.	Buckwheat	1
Penstemon spp.	Penstemon	1
Atriplex gardneri	Gardner's Saltbush	2
Atriplex canescens	Fourwing Saltbush	1
Oryzopsis hymenoides	Indian Ricegrass	2
	Total	21

Saline Upland Mixture

Species	Common Name	PLS lbs/acre
Agropyron dasystachyum	Thickspike Wheatgrass	3
Agropyron riparium	Streambank Wheatgrass	1
Agropyron spicatum	Bluebunch Wheatgrass	2
Agropyron trachycaulum	Slender Wheatgrass	2
Atriplex canescens	Fourwing Saltbush	1
Atriplex gardneri	Gardner's Saltbush	2
Chrysothamnus nauseosus	Rubber Rabbitbrush	2
Ceratoides lanata	Winterfat	2
Poa compressa	Canada Bluegrass	2
Lupinus spp.	Lupine	1
Erigonum spp.	Buckwheat	1
	Total	15

Sands Mixture

Species	Common Name	PLS lbs/acre
Agropyron dasystachyum	Thickspike Wheatgrass	3
Agropyron riparium	Streambank Wheatgrass	1
Agropyron spicatum	Bluebunch Wheatgrass	2
Agropyron trachycaulum	Slender Wheatgrass	2
Stipa comata	Needle-and-thread	1
Chrysothamnus nauseosus	Rubber Rabbitbrush	2
Festuca ovina	Sheep Fescue	1
Lupinus sp.	Lupine	1
Penstemon spp.	Penstemon	1
Oryzopsis hymenoides	Indian Ricegrass	3
Artemisia cana	Silver Sage	3
Eriogonum spp.	Buckwheat	1
	Total	19

MINE WY-4

Basic Mixture

Species	Common Name	PLS lbs/acre
Agropyron dasystachyum	Critana Thickspike Wheatgrass	2.0
Agropyron smithii	Rosana Western Wheatgrass	2.5
Agropyron inerme	Whitmar Beardless Bluebunch Wheatgrass	1.5
Agropyron trachycaulum	Slender Wheatgrass	2.0
Oryzopsis hymenoides	Indian Ricegrass	2.0
Atriplex canescens	Fourwing Saltbush	1.0
Atriplex confertifolia	Shadscale Saltbush	1.0
	Total	12.0

plus one experimental species from the following: intermediate wheatgrass (Agropyron intermedium), streambank wheatgrass (Agropyron riparium), Siberian wheatgrass P-27 (Agropyron sibericum), pubescent wheatgrass (Agropyron trichophorum), blue grama (Bouteloua gracilis), smooth brome (Bromus inermis), basin wildrye (Elymus cinereus), Russian wildrye (Elymus junceus), needle-and-thread (Stipa comata), green needlegrass (Stipa viridula), and black greasewood (Sarcobatus vermiculatus),	1.0

on bottomlands and north facing slopes

Artemisia tridentata	Big Sagebrush	0.5
Chrysothamnus nauseosus	Rubber Rabbitbrush	0.5
	Experimental Shrub	0.25

APPENDIX C

GLOSSARY

GLOSSARY

Aspect -- The direction a slope faces; affects temperature, moisture (e.g., snow accumulation and retention), and wind exposure, and hence can dramatically influence vegetation.

Carrying Capacity -- The amount of livestock or wildlife use that an area is able to support; relates to forage production, water, shelter, etc.

Climax -- The kind of community capable of perpetuation under the prevailing climatic and substrate conditions, assuming long-term absence of disturbance. See "succession."

Constancy -- How uniformly a plant species occurs in numerous plant communities of the same vegetation type.

Coulee -- A term used especially in the Upper Midwest and Northwest for a drainageway that is steep-sided and normally is dry by late summer. When dominated by shrubs and subshrubs, also called woody draws. Coulees often support plant and animal species otherwise not found in an area.

Cover (Absolute) -- The percentage of the ground covered by above-ground portions of plants; may be expressed by species, lifeform, or totaled; values for litter, rock, and soil may be similarly reported.

Cover (Relative) -- The proportion of the total absolute cover contributed by each plant species.

Cropland -- An area of vegetation that is harvested, including row crops (e.g., corn), small grains (e.g., wheat and barley), and hay (forage grasses and other herbaceous plants regularly mown to produce forage for winter use).

Diversity -- The variation or heterogeneity of species or lifeforms within one plant community, which may incorporate "richness" (species or lifeform number) and "evenness" (comparative species or lifeform abundance).

Diversity -- Landscape -- Variation or heterogeneity between plant communities and landforms in a landscape..

Forb -- A nongrassy (i.e., broadleaf) herbaceous plant; includes many species commonly referred to as wildflowers or weeds.

Grassland -- An area of vegetation dominated by grasses, with other types of plants (e.g., shrubs) present in low numbers.

Grazingland -- Any area used primarily to support livestock, including both "native rangeland" and "pastureland" (see respective definitions).

Herbaceous -- A type of plant with no woody parts (e.g., grasses and forbs).

Hydromulch, Hydroseed -- Methods of applying wood fiber mulch or seed by spraying them in a water-based mixture from a water cannon; advantages are that the methods are fast and can be used to reach steep or otherwise inaccessible sites; disadvantages are sometimes poor seed/soil contact and seed dmage.

Frequency -- How uniformly a plant species occurs within one local plant community.

Lifeform -- Structural categories of plant types, commonly set forth as annual grass, perennial grass, annual forb, perennial forb, subshrub, shrub, tree, etc.

Line Intercept -- A method of estimating plant cover by mesaurement of the interception of vertical projection of plant canopies or parts along a horizontal line.

Litter -- Undecomposed dead plant parts accumulated at the ground surface.

Mesic and Xeric -- Used to describe sites that are relatively moist and relatively dry, respectively.

Morphologic -- Pertaining to shape or configuration.

Mycorrhizal -- Referring to the symbiotic relationship of certain fungi with the roots of plants; this relationship often enhances the uptake of water and nutrients from the soil into the roots.

Native Rangeland -- Grazingland dominated by naturally occurring plant species; generally requires low levels of active management other than controlling the intensity, season, and duration of use by livestock.

Nurse Crop -- A short-lived plant cover (e.g., annual grains) sometimes planted in the initial year of revegetation to protect the seedlings of perennial species from desiccation by sun or wind. A related practice is mowing the annual plant cover in the fall prior to the perennials' planting, thereby producing a "stubble mulch."

Pastureland -- Grazingland dominated by ("tame") introduced grasses and forbs (e.g., alfalfa, clover) that is highly productive but requires moderate to high levels of active management such as fertilizers, periodic reseeding, and weed control. Often "rotated" in use with hayland or allowed to periodically "rest" (i.e., lie fallow).

Phytotoxic -- Poisonous to plants.

Plant Association -- A unit of variable meaning in plant ecology implying internal similarity of (a) existing species composition or (b) lifeform structure, or (c) potential natural vegetation.

Plant Community -- A group of plant populations occurring together under similar ecologic conditions and having recognizable limits.

Playa -- As recognized in the Northern Great Plains, a shallow depression with no external drainage that holds water for part of the year and is usually from less than one to tens of acres in size. The occasional inundation and tendency for development of heavy claysoils results in distinctive vegetation tolerant of such conditions.

Point Intercept -- A method of estimating cover by the interception of above-ground plant parts (and litter, rock, or soil) by a vertically projected point, as defined by a sharp pin or by cross-hairs in a viewing device.

Potential Natural Vegetation -- An abstraction defined as the persisting vegetation that would become established if all successional sequences were allowed to proceed to completion without interference by human activity under the present climatic and substrate conditions.

Pure Live Seed (PLS) -- Used as a basis for reporting seeding rates, eliminating variation in bulk seed trash content and seed germinability.

Production -- The weight (usually oven dry) of annual growth of above-ground plant parts (i.e., "standing crop"); usually expressed as weight ("biomass") per unit land area.

Propagule -- Plant tissue which, if separated from the plant, will give rise to a new individual (seeds, certain types of buds, etc.).

Quadrat -- A plot of variable size, used to measure or estimate a vegetation parameter such as production or cover.

Random Sampling -- Collection of data from sites selected by chance, in contrast to sites selected at regular intervals (systematic sampling) or on the basis of perceived representativeness (subjective sampling).

Range Site -- A vegetation unit traditionally defined as an area where the physical environment (topographic, soils, and climate) are sufficiently uniform to produce the same potential or climax vegetation. (Compare to "vegetation type.")

Relict -- Used to describe an area of vegetation that is the remnant of a formerly more widespread type.

Riparian -- Lands adjacent to flowing water; usually refers to streamside vegetation.

Seasonality -- In plant ecology, refers to the time of the growing season when maximum growth occurs; especially used to differentiate between cool-season grasses (peak growth in spring and fall) and warm-season grasses (peak growth in summer).

Shrub -- A perennial woody plant, smaller than a tree and typically with more than one main stem, whose over-wintering buds are borne on twigs above the ground.

Shrub-Steppe -- An area of dry grassland supporting substantial numbers of shrubs distributed throughout.

Subshrub -- A perennial plant which is woody at its base and is either of small stature or dies back nearly to ground level (i.e., intermediate between a shrub and a forb).

Succession -- The natural progression of plant communities following partial or complete disturbance; theoretically culminates in the "climax" community.

t-test -- A statistical procedure designed to test for a significant difference between two sets of data, such as between production values of revegetated and reference areas.

Transect -- A line or narrow belt along which ecologic data are collected, either continuously (e.g., total counts of trees) or periodically (e.g., periodic location of cover or production samples).

Vegetation Type -- A mappable unit of vegetation based primarily on existing, dominant species or lifeform composition; may also include reference to soils and topography that affect existing vegetational composition (e.g., playa grassland, upland big sagebrush, riparian mixed woodland).

Woody Plant -- Any perennial plant which produces wood fibers in its above-ground parts and whose over-wintering buds are borne above the ground; includes trees, shrubs, and subshrubs.

WILDLIFE TECHNOLOGIES
FOR
WESTERN SURFACE COAL MINING

Prepared For:
ENERGY AND MATERIALS PROGRAM
Office Of Technology Assessment
UNITED STATES CONGRESS
Washington, D.C. 20510

Prepared by:
CEDAR CREEK ASSOCIATES
PO Box 9557
916 Willshire Ave.
Fort Collins, Colorado 80525

Authors:
T. Michael Phelan
Steven R. Viert
Stephen G. Long

TABLE OF CONTENTS

Page

List of Tables iii
List of Figures iv
1.0 INTRODUCTION 1
1.1 Background and Purpose 1
1.2 Research Methods and Data Sources 2
1.3 Study Approach and Report Organization 3
1.4 Acknowledgements 5

2.0 OVERVIEW 6
2.1 Chapter Introduction 6
2.2 General Habitat and Wildlife Species Considerations 8
2.3 State Wildlife Baseline Data Requirements 16
2.4 Wildlife Baseline Data and Collection Methodologies 31
2.5 Impact Assessment 51
2.6 Wildlife Mitigation Techniques and Success Determination 55

3.0 CASE STUDIES 70
3.1 Chapter Introduction 70
3.2 Mine A 73
3.3 Mine B 81
3.4 Mine C 91
3.5 Mine D 101
3.6 Mine E 112
3.7 Mine F 123
3.8 Mine G 131
3.9 Mine H 141
3.10 Case Study Summary 145

4.0 ANALYSIS 147
4.1 Chapter Introduction 147
4.2 Evaluation of Impact Assessment and Mitigation Success Determination 147
4.3 Baseline and Monitoring Data Evaluation 153

5.0 ISSUES, DATA GAPS, AND RESEARCH NEEDS 158
5.1 Chapter Introduction 158
5.2 Overview of Innovative Mitigation 158
5.3 Legal Constraints 162
5.4 Long-term Monitoring and Research 165
5.5 Post-mining Land Use Conflicts 166
5.6 Habitat Reclamation Standards Not Related to Vegetation 167
5.7 Cumulative, Regional, and Secondary Mining Impacts 170
5.8 Other Issues 171

TABLE OF CONTENTS (Continued)

5.9 Summary of Research Needs 175
6.0 CONCLUSIONS 177
7.0 REFERENCES CITED.. 179
8.0 GLOSSARY 180

APPENDICES

Appendix A: Interview Forms
Appendix B: State Coal Mining Wildlife Regulations
Appendix C: State Wildlife Guidelines
Appendix D: Selected Baseline Methodology and Mitigation Manuals

LIST OF TABLES

Page

Table 1: Accepted Data Collection Techniques 19
Table 2: Wildlife Baseline Data and Survey Techniques 42
Table 3: Survey Techniques And Associated Methodologies 45
Table 4: Selected Mitigation Techniques Listed By General Category 56
Table 5: Selection Criteria for Wildlife Discipline Case Studies 71
Table 6: Wildlife Methods and Data Collected for Species Groups at Mine A 77
Table 7: Wildlife Methods and Data Collected for Species Groups at Mine B 85
Table 8: Wildlife Methods and Data Collected for Species Groups at Mine C 95
Table 9: Wildlife Methods and Data Collected for Species Groups at Mine D 104
Table 10: Wildlife Methods and Data Collected for Species Groups at Mine E 116
Table 11: Wildlife Methods and Data Collected for Species Groups at Mine F 126
Table 12: Wildlife Methods and Data Collected for Species Groups at Mine G 134
Table 13: Wildlife Methods and Data Collected for Species Groups at Mine H 143
Table 14: Identified Issues and Research Needs 159

LIST OF FIGURES

Page

Figure 1 - Example of Big Game Pellet Group Data Submitted in Permit Application 33
Figure 2 - Example of Avian Data Submitted in Permit Application 34
Figure 3 - Example of Small Mammal Data Submitted in Permit Application 35
Figure 4 - Example of Mapped Data Submitted in Permit Application 36
Figure 5 - Example of Wyoming Game and Fish Department Computerized Wildlife Information Mapping 38
Figure 6 - Conveyor System Underpass Structure Design for Mule Deer Passage 62
Figure 7 - Typical Deer-Proof Fencing with One-way Gates 63
Figure 8 - Example of Electrocution Proof Powerpole for Raptors 64
Figure 9 - Typical Tree/Shrub Planting for Wildlife Habitat Enhancement 65
Figure 10- Typical Rock Pile Configuration for Enhancement of Wildlife Habitat 66

1.0 INTRODUCTION

1.1 Background and Purpose

Recent analyses of the Federal Coal Management Program, including the Office of Technology Assessment's (OTA) report on "Environmental Protection in the Federal Coal Leasing Program" (OTA 1984) have raised concerns regarding: 1) use of baseline and monitoring data; 2) the effectiveness of lease stipulations and permit conditions; 3) methodologies for evaluating or predicting impacts or the success of reclamation practices; and 4) the introduction of new reclamation techniques. As a result of these concerns, the House Interior and Insular Affairs Committee requested the OTA to evaluate the effectiveness of current reclamation methodologies and Federal programs and policies in fulfilling the statutory mandates for environmental protection on Federal lands in the West.

The purpose of this report is to assist the OTA in a portion of its evaluation by providing an assessment of: 1) data and analytical techniques used to assess or predict wildlife impacts related to surface coal mining in the West; 2) reclamation technologies and methodologies used to mitigate wildlife impacts during and after mining; and 3) data, analytical techniques, and monitoring used after mining to evaluate the success of wildlife mitigation techniques or wildlife habitat restoration. In addition, this report will make recommendations for improving uses of data and for research to address areas where existing information is inadequate.

The general study area encompassed by this report included primarily areas of Federal land or coal within the major surface coal producing regions located in northwest Colorado, eastern Montana, northern New Mexico, western and central North Dakota, and northeastern and southern Wyoming.

1.2 Research Methods and Data Sources

The summaries and assessments of data, methodologies, and techniques presented in this report are based primarily on existing information, interviews with federal and state regulatory and industry wildlife personnel, and the background and experience of the authors. The authors have had direct experience in collecting wildlife and revegetation data and preparing the wildlife baseline, wildlife mitigation, and reclamation sections of numerous permit applications for surface coal mines in the region addressed by this report.

Information collection for this report consisted of reviews of state and federal surface coal mining and wildlife regulations, guidelines, and policies; interviews with state and federal regulatory, state game and fish agency, and industry personnel; and a review of coal mining permit applications, mine monitoring reports, and state and federal decision documents. Interviews with private and public research or environmental groups were conducted and reviews of additional pertinent literature pursued as appropriate. All interviews with regulatory agency, fish and game agency, or industry personnel employed standardized questionnaires to ensure adequate coverage of information required to complete this report.

Sample copies of these interview forms are provided in Appendix A. Primary state and federal agencies contacted for interviews and information collection are listed below:

COLORADO
- Colorado Mined Land Reclamation Division (CMLRD)
- Colorado Division of Wildlife (CDOW)

MONTANA
- Montana Department of State Lands (MDSL)
- Montana Department of Fish, Wildlife and Parks (MDFWP)

NEW MEXICO
- New Mexico Energy and Minerals Department - Mining and Minerals Division (MMD)
- New Mexico Department of Game and Fish (NMDGF)

NORTH DAKOTA
- North Dakota Public Service Commission (NDPSC)
- North Dakota Department of Game and Fish (NDDGF)

WYOMING
- Wyoming Department of Environmental Quality - Land Quality Division (DEQ-LQD)
- Wyoming Game and Fish Department (WGFD)

FEDERAL AGENCIES
- U.S. Fish and Wildlife Service Region 6 and Coal Coordinator Offices (USFWS)
- U.S. Bureau of Land Management Resource Area Wildlife Specialists (BLM)
- Office of Surface Mining - Region V (OSM)

1.3 Study Approach and Report Organization

This report is divided into four sections: Overview, Case Studies, Analysis, and Issues.

1.3.1 Overview

This section summarizes baseline data collection methods, types of baseline data collected, impact assessment techniques, and mitigation techniques and success standards employed to address wildlife resources affected by surface coal mining activities. Included as a portion of this task are discussions comparing individual state requirements for data collection, data analysis, and monitoring to assess impacts and mitigation success. General information on sources, format, locations, and accessibility of data also is provided. In addition, discussions regarding geographical areas of coverage and potential future uses of data are provided, where applicable.

1.3.2 Case Studies

For this task, eight surface coal mines were selected to illustrate specific wildlife concerns related to surface mine development and how these concerns were addressed. For each case study, data collection techniques, types of data collected, methods used to assess and mitigate wildife impacts, and procedures and criteria used to evaluate the success of mitigation are presented. Case studies were chosen to represent a variety of wildife concerns and environmental settings.

1.3.3 Analysis

Based on information presented in the overview and case studies, the analysis section examines and evaluates the adequacy and applicability of existing baseline and monitoring data for impact assessment and mitigation success determination. Suggestions for improved data format, uses of data, and research needs also are made. In addition, the adequacy of existing analytical techniques used to predict impacts or gauge mitigation success are evaluated.

1.3.4 Issues, Data Gaps, and Research Needs

Issues, data gaps, and research needs identified in this report are presented and discussed in this section. Some of the issues presented are not specifically identified by the case studies but were compiled based on interviews with agency and industry personnel. Where possible, suggestions for research or other potential solutions are offered to address these issues.

1.4 Acknowledgements

The authors of this report wish to thank all the industry and state and federal agency personnel who contributed their time and effort to our interview process and provided valuable insight and suggestions that assisted us in our timely completion of this document.

2.0 OVERVIEW

2.1 Chapter Introduction

This chapter begins by providing brief descriptions of the habitat characteristics and important wildlife issues in the five-state study area. For convenience, these descriptions are presented by state and focus primarily on the major surface coal producing regions. Following these descriptions, the general emphasis, goals, and objectives of each state's surface coal mining requirements and guidelines for wildlife baseline data collection are discussed and compared. General information on sources, accessibility, format, and uses of data also is provided and compared by state, where applicable. Information on data collectors, data collection techniques, and resultant data is summarized in Section 2.4. The remaining portions of this chapter (Section 2.5 and 2.6) provide an overview of the range of wildlife impact assessment procedures, mitigation measures, and mitigation success evaluation techniques used to address wildlife issues.

In this chapter and ensuing chapters certain descriptive terminology is used to characterize the methodologies used in the science of wildlife biology. This terminology is used consistently throughout this report and may be used in a slightly different context than commonly used outside the science of wildlife biology. Because of this, definitions for these terms, as they are used in this report, are provided below.

Analytical =

An analytical process is one that uses standard arithmetic or numerical, algebraic, trigonometric, statistical, or calculus mathematical procedures to derive or compare values with regard to ecological parameters and variables.

Statistical =

Mathematical procedures used to determine probabilites regarding inexact variables and ever changing conditions to define generalities from specific observations or data.

Numerical =

An arithmetic procedure to assign exact values to specific observations.

Quantitative =

Quantitative analyses or procedures use an analytical process to provide mathematical values or descriptions for unknown situations conditions, or ecological parameters.

Qualitative =

Qualitative analyses or procedures use non-analytical data, experienced judgement, and intuition to provide descriptions of unknown situations, conditions, or ecological parameters.

Semi-quantitative =

Analyses or procedures using a variable combination of quantitative and qualitative information to provide descriptions of unknown situations, conditions, or ecological parameters.

As identified in this report, qualitative and semi-quantitative procedures are used more frequently than strictly quantitative procedures to describe ecological variables, analyze impacts, and determine appropriate mitigation measures. As discussed later in this chapter this situation reflects the inherent difficulties involved with quantitative measurement of wildlife parameters and habitat characteristics. Often, qualitative judgements based on experience have proven to be satisfactory for defining unmeasureable ecological parameters and assessing potential impacts. In addition, qualitative or semi-quantitative procedures have been found, in many cases, to be more efficient and cost-effective than extensive quantitative procedures. However, in particular instances, quantitative data and analyses may be necessary or required to address specific unknowns or perform assessments.

2.2 General Habitat and Wildlife Species Considerations

These descriptions primarily address the terrestrial habitat and wildlife resources of the study regions within each state. Descriptions of habitats that are similar between states are not repeated. Aquatic habitat potentially affected by surface coal mining in the West is limited and consists predominately of small wetlands, stockponds, small streams, and ephemeral drainages. These aquatic features generally do not support important fisheries or provide necessary habitat requirements for legally protected or state sensitive species. For the most part, the importance of aquatic habitats for wildlife in western surface coal mining areas is related to use by terrestrial species. Potential impacts to these resources result, for the most part, from increased sedimentation, contamination, temporary disruption of flow, and removal. Measures used to address and mitigate these potential hydrologic impacts are discussed in the hydrology companion document in Sections 2.3 and 4.3. The importance of wetlands and other surface water to terrestrial wildlife is however, addressed in this document.

2.2.1 North Dakota

Mid-grass and mixed mid- and shortgrass prairie are the climax biotic communities in the surface coal mined portions of western and central North Dakota. Much of this native prairie has either been converted to cropland or altered by overgrazing of livestock. Intensive grazing has resulted in a reduction of mid-grasses and a proliferation of the more grazing-resistant shortgrass and introduced species. For prairie and cropland habitats, the more obvious wildlife species are white-tailed deer, pronghorn, red fox, open country raptor species, ring-necked pheasant, and sharp-tailed grouse.

Habitats occuring to a much lesser extent than grassland or cropland, of greater concern because they are difficult to reclaim, and are limited in extent, include badlands, wetlands, and broadleaf tree and shrub communities. Badlands are composed of a mosaic of different topographic features and vegetation species including a wide variety of grass and shrub species. They generally are characterized by sparsely vegetated clay or scoria slopes interspersed with small trees and shrubs in the valleys or on stable north-facing slopes. Broadleaf tree and shrub communities occur along perennial and intermittent drainages and along the bottoms of more mesic draws and coulees. Due to the diversity of vegetation and cover provided by badlands and broadleaf communities, and the usual association of broadleaf vegetation with seasonal or permanent surface water, the relative importance of these communities to wildlife is disproportionately greater than their areal extent. In addition, features such as trees, escarpments, and knobs associated with badland and broadleaf habitats often provide the only suitable nesting habitat for several species of raptors that breed in the Northern Great Plains. Other common wildlife species dependent upon these habitats for forage and cover include mule deer, white-tailed deer, pronghorn, furbearers, and a variety of migratory and breeding songbirds.

Wetlands in this region generally are small in areal extent, most often developing in rainwater catch basins and in shallow depressions where groundwater reaches the surface. Wetlands support a great variety of wildlife species, many of which enter from adjacent habitats to temporarily obtain food, cover, or water and to breed. Of greatest importance is the habitat wetlands provide for migratory and breeding waterfowl and shorebirds.

2.2.2 Montana

The principal climax biotic community for eastern Montana is shortgrass prairie. This community is interspersed with smaller tracts of badlands, broadleaf shrub and tree associations, shrub steppe, ponderosa pine woodland, and, to a much lesser extent, wetland habitats. Ecological characteristics of prairie, badland, broadleaf, and wetland habitats are similar to those described for North Dakota. Shrub steppe communities in Montana occur primarily as stands of sagebrush with a variety of grasses and forbs occurring in the understory. Common wildlife occurring in shrub-steppe communities include mule deer, pronghorn, cottontail, sage grouse, sharp-tailed grouse, and several species of raptors. Sagebrush is an important food source for pronghorn and mule deer, and is essential to all aspects of the life history of sage grouse.

Ponderosa pine woodland is characterized by open stands of ponderosa pine that include scattered Rocky Mountain juniper trees. The understory consists of a diversity of shrubs, forbs, and grasses. Ponderosa pine woodland occurs primarily in broken hilly or rolling terrain. Topographic diversity, good floral cover, and the variety of forage species make this an important wildlife habitat. Mule deer, white-tailed deer, wild turkey, sharp-tailed grouse, and woodland raptor species are common residents of ponderosa pine woodland.

2.2.3 Wyoming

Sagebrush steppe, grassland, and to a lesser extent, riparian areas, ponderosa pine, and juniper woodlands are the major native habitats in northeastern Wyoming. Similar habitats are present in the coal producing regions of southern Wyoming, although grasslands are less dominant. Reduced rainfall in the southern region limits floral diversity and density. In addition, greasewood and saltbush shrubs thrive on alkaline soils here, with saltbush occurring on drier upland areas, and greasewood dominating lowland areas where the water table is relatively close to the surface. Rimrock habitat is also more common in southern Wyoming than in northeastern Wyoming.

Riparian vegetation, consisting of tall sagebrush, willows, and cottonwoods, occurs along permanent and intermittent water courses in these regions. Riparian habitats are valuable as a water source for all wildlife; supply food and cover for mule deer, furbearers, and wild turkey; and provide nesting habitat for raptors, waterfowl and shorebirds. In addition, riparian areas are used by a variety of woodland wildlife species as movement corridors.

Juniper habitat usually occurs as open woodland with a shrub understory on areas overlain by shallow soils such as hillsides and ridges. Juniper woodland frequently is used by mule deer as a more important wintering area.

Rimrock or escarpments are physical habitat features that can occur in a variety of vegetation communities. Rimrock serves as nesting or denning sites for many species of mammals, birds, and reptiles. Golden eagle, red-tailed hawk, great horned owl, and prairie falcon commonly nest on ledges or in cavities in rimrock. Rimrock also can serve as protective cover for animals during winter storms or collect additional moisture to support a greater variety of shrubs or trees not found in adjacent communities.

2.2.4 Colorado

Wildlife habitats on the surface mined coal regions of northwest Colorado consist of sagebrush, mountain shrub, meadow, pinyon-juniper, aspen and riparian communities. Sagebrush habitat occurs over wide elevational ranges and intergrades to a certain extent with all other habitats. Extensive stands occur in mountain parks and basins Additional moisture received by this region, makes the herbaceous understory of the sagebrush community more dense and diverse than that of this community in Wyoming and Montana. As discussed above, sagebrush is an important browse species for mule deer, especially on snow-free slopes in the winter. It also is an important feeding, breeding, and brood-rearing habitat for sage grouse. Sagebrush openings near aspen stands (used as elk calving habitat) represent important elk calf-rearing areas.

Mountain shrub communities occur on the moister hillsides in this region, usually as a transition zone between sagebrush and aspen or coniferous forest communities. This community is characterized by a diverse flora dominated by shrubs or small trees. Common shrub species include chokecherry, scrub oak, serviceberry, antelope bitterbrush, and mountain mahogany. The dominant shrub species varies depending on the characteristics of a specific site. In areas where the shrub overstory is relatively open and varied, the herbaceous understory usually is diverse and wildlife forage plentiful. Such areas support a wide variety of mammalian and avian species. Where dense monotypic stands of shrubs are present (as in severely overgrazed areas or in overmature stands), the understory usually is sparse and wildlife use of these areas is more limited. Mountain shrub communities are used extensively by elk, mule deer, sharp-tailed grouse, blue grouse, and cottontails, as well as a variety of other species. These communities provide critically important food and cover to mule deer and elk during the winter months, especially on slopes where exposure limits snow accumulation. In areas where snow accumulates to sufficient depths to hamper elk and deer movement, winter use of mountain shrub slopes is limited.

Meadow communities occur primarily as narrow bands of grassland along drainages and as isolated pockets in sagebrush or aspen habitat. These communities are characterized by the lack of a tree or shrub stratum and by a diverse herbaceous cover consisting of perennial forbs and grasses. Meadow habitat increases floral diversity in extensive stands of aspen or sagebrush and often contributes to "edge effect" -- the edges of, or transition zones between, habitats often are preferred by wildlife. Livestock and wildlife species, including elk, mule deer, and sage grouse, use meadow habitat extensively for feeding during the spring when succulent forbs and grasses are present. Meadow habitat has been shown to be a particularly important foraging area for sage grouse broods in spring and early summer.

Pinyon-juniper habitat is ecologically similar to juniper habitat in Wyoming except that pinyon pines are present. In most areas, juniper is still the dominant tree with only scattered individual pinyon pines present. The presence of pinyon pine in the overstory increases the overall floral diversity of this woodland community and provides a valuable food source (e.g., pinyon nuts) for a variety of small mammals and birds.

Aspen communities are found on moist sites at higher elevations throughout this region. Aside from riparian communities, aspen stands represent the only deciduous forest in the region. Aspen communities frequently support a lush herbaceous understory of grasses and forbs. In addition, a variety of shrubs including serviceberry, snowberry, and chokecherry are present in the understory in varying densities depending on the extent of aspen canopy coverage. During the winter months, aspen habitat usually exhibits significant accumulations of snow cover which precludes big game use of this habitat for winter range. During the other seasons, elk and mule deer extensively use aspen stands for food and thermal cover. Aspen communities also can be used by elk for calving habitat in the spring. Other wildlife characteristically associated with aspen include beaver, blue grouse, woodland raptors, and numerous woodland songbird species.

Ecological characteristics of riparian habitats are similar to those described for Wyoming except that in the moister and more mountainous portions of northwestern Colorado the floral diversity of the tree and shrub stratum generally is greater. Common woody species include cottonwood, aspen, alder, birch, box elder, ash, and willow.

2.2.5 New Mexico

Two surface coal-producing regions in New Mexico are addressed in this report, the Raton Basin and the San Juan Basin, both in the northern portion of the state. Vegetation communities potentially affected by surface mining in the Raton Basin region include grassland, pinyon-juniper, oak/mixed shrub, riparian, and mixed conifer/ponderosa pine. Ecological characteristics of the grassland, pinyon-juniper, mixed shrub, and riparian communities are generally similar, though somewhat drier at equivalent elevations, to these communities in the regions described previously. Ponderosa pine and Douglas-fir are the dominant tree species occurring in mixed conifer/ponderosa forests. At the lower elevations ponderosa pine forms a savannah-like forest that permits the development of a grassland understory. With increasing elevation, ponderosa pine density increases, and then intergrades over a broad zone with Douglas-fir. Elk, mule deer, black bear, and forest-dwelling raptors are some of the common species in these communities.

In the San Juan Basin, dry grasslands, pinyon-juniper, badlands, greasewood/saltbush, and desert shrub communities are predominant. This region is the dryest of those addressed by this report. Vegetation is sparse and typically slow to reestablish following disturbance. Saltbush and snakeweed are dominant shrubs in the desert shrub communiites, especially in areas where soils are alkaline or disturbed. Typical wildlife inhabitants of desert shrub communities include black-tailed jackrabbit, badger, burrowing small mammals (e.g., kangaroo rats), and a variety of reptiles. Mule deer and pronghorn are present occasionally.

2.3 State Wildlife Baseline Data Requirements

Wildlife data collected, baseline data collection techniques, and data analysis techniques are generally the same for North Dakota, Montana, Wyoming, Colorado, and New Mexico. State requirements differ primarily with regard to the intensity, duration, and focus of baseline studies rather than techniques or types of data required. (Data collected prior to disturbance by a mining operation forms a background source of information from which to base future decisions upon - hence the name "baseline data".) A summary and discussion of these techniques is provided in Section 2.4.

Each state's surface coal mine wildlife regulations are listed in Appendix B. Copies of state guidelines developed to assist operators in satisfying these regulations are provided in Appendix C for those in which they have been developed.

Specific baseline studies or implementation of specific analytical techniques for surface coal mine operations are required in all five states on a case-by-case basis depending on existing habitats and wildlife resources at a given operation. Only a few state wildlife regulations are required automatically for all surface coal mining operations, unlike the regulations governing disciplines such as vegetation and soils. State regulations for required wildlife baseline studies have remained relatively flexible to account for large differences in habitat characteristics and wildlife populations across the coal producing regions of a state. Wildlife baseline programs for specific mine operations are almost always formulated through consultation between the operator or his consultant, and the regulatory authority along with the state game and fish agency. Even after the extent of required studies are determined, the emphasis of these studies or the amount or kind of data required may change depending on the findings of initial studies.

All five states' regulatory authorities rely on the state game and fish agencies (and to a lesser extent on U.S. Fish and Wildlife Service and Bureau of Land Management wildlife personnel) to provide guidance to coal mine operators and the regulatory authority in formulating required wildlife baseline studies. The USFWS' jurisdiction in providing consultation relates primarily to protection of Federally listed threatened and endangered species, eagles, and migratory bird species as mandated by the "Endangered Species Act", Bald Eagle Protection Act", and "Migratory Bird Treaty Act". Most of the species covered by these acts are also protected or regulated by state laws. In addition, many states have laws protecting state listed threatened, endangered, rare, or sensitive species that may not be protected by Federal laws.

States' wildlife requirements differ primarily in the use of formal guidelines, intensity and duration of baseline studies, emphasis of required studies, and habitats and species present within the state. Summaries of the wildlife requirements in each state are provided below. Information in these summaries was derived solely from regulations and guidelines for the respective states and from interviews with personnel from the state mining regulatory and fish and game agencies listed in Section 1.2.

2.3.1 North Dakota

GUIDELINES. The North Dakota legislature does not allow the use of formal written guidelines on the theory that formal requirements should be subject to the administrative procedures for rulemaking. Informal guidelines are issued by the Public Service Commission (PSC) in technical memoranda.

EMPHASIS OF REQUIRED STUDIES. Because of their limited extent and importance as wildlife habitat, the greatest concern to the state is inventories of wildlife in woody draws, wetlands, and native prairie. The state also stresses the need for habitat descriptions and mapping of these habitats.

REQUIRED STUDIES. Studies are required on a case-by-case basis for each mine. However, these studies are fairly standard for each different habitat present (see Table 1). New mines must complete site-specific studies; the PSC does not allow substitution of data and studies from

Table 1

Accepted Data Collection Techniques [1]

Study Category	North Dakota	Montana	Wyoming	Colorado	New Mexico
Big Game	- Aerial survey - late winter	- Aerial surveys - 2/month - Browse transects - Scat and stomach examination	- Aerial and ground surveys - late winter, summer, late fall	- Aerial and ground surveys - winter, late spring - Pellet group and browse surveys	- Aerial surveys (2) - spring and fall
Furbearers	- Trapping only in woodlands - fall	- Incidental observations	- Incidental observations	- Incidental observations	- Spotlight surveys - all seasons - Systematic observation of scat and tracks - all seasons
Small Mammals	- Trapping only in woodlands - fall	- Live and snap trapping - spring and fall [grid trapping preferred in all habitats including reclaimed and undisturbed (control) habitats]	- Live and snap trapping - late spring or summer (transects, grids, or clusters depending on habitat)	- Live and snap trapping - late spring or summer (transects)	- Live and snap trapping in all habitats - spring and fall - Voucher specimens required
Raptors	- On-foot nest searches - spring - If extensive woodlands are present, aerial nest surveys prior to leaf-out	- Ground and aerial nest surveys - spring	- Ground and/or aerial nest surveys - spring	- Ground and/or aerial nest surveys - spring	- Aerial and/or ground nest surveys - spring
Waterbirds	For all wetlands: - breeding pair counts - May-June - brood counts - July - migration counts - April, October	For all surface water: - routine counts - 1/month - no migratory or brood surveys	For all surface water: - seasonal counts including breeding pair and brood counts	- Incidental observations	For all surface water: - breeding bird surveys - spring/summer - migratory surveys may also be required - fall, winter

Table 1 Continued

Study Category	North Dakota	Montana	Wyoming	Colorado	New Mexico
Upland Game Birds	- Pheasant crowing call counts - April, June - Aerial and ground lek location surveys - spring - Breeding bird lek counts - spring	- Pheasant crowing call counts - spring - Aerial and ground lek location surveys - spring - Breeding bird lek counts - 2/spring - Where leks will be disturbed, intensive telemetry studies are required to determine habitat needs - Crop examination	- Aerial and/or ground lek location surveys - spring - Breeding bird lek counts - spring - Vehicle or on-foot production surveys	- Aerial and/or ground lek locations surveys - spring - Breeding bird lek counts - spring	- Breeding bird surveys - spring/summer
Songbirds and Others	- Variable width belt transects only in woodlands - spring - Road survey - winter	- Variable width belt transects in all habitats - spring	- Variable width belt or point transects in all habitats and some habitat edge areas - spring	- Variable width belt transect or variable circular plot in all habitats - spring	- Variable width belt transect - spring/summer
Reptiles and Amphibians	- Incidental observations	- Incidental observations	- Incidental observations - Trapping and call surveys in appropriate habitats - spring, early summer	- Incidental observations	- Systematic surveys - spring, fall
Aquatic Vertebrates and Invertebrates		- Electro-shocking, seining, bottom sampling, dredging, etc. as appropriate (only for waters potentially affected by mining)	- Stream quality classification - Electro-shocking, seining, bottom sampling, dredging, etc. as appropriate	- Stream habitat classification - Electro-shocking, seining, bottom sampling, dredging, etc. as appropriate	- Electro-shocking, seining, bottom sampling, dredging, etc. as appropriate - seasonally

Table 1 Continued

Study Category	North Dakota	Montana	Wyoming	Colorado	New Mexico
Threatened and Endangered Species	- No T & E critical habitats affected by mining - Notification of observations required	- Black-footed ferret: full USFWS guideline search of prairie dog towns - Bald eagle (Tongue R. only): aerial and ground surveys for roost or concentration areas - winter only	- Black-footed ferret: density estimation and mapping prairie dog towns; full USFWS guideline search of all of towns - Bald Eagle: aerial surveys for winter concentration areas	- Black-footed ferret: full USFWS guideline search of all prairie dog towns - Bald eagle: aerial or ground surveys for roost sites or winter concentration areas	- Black-footed ferret: full USFWS guideline search of all prairie dog towns
All Wildlife Species	- Incidental observations	- Incidental observations	- Incidental observations	- Incidental observations	- Incidental observations
Habitat	- Habitat mapping at 1:4800 scale - Distinct communities within a wetland must also be mapped	- Delineation and mapping	- Classification, delineation, and mapping	- Delineation and mapping of all habitats and habitat features	- Characterization, delineation and mapping of all habitats

---

1/ This table is not intended to represent a listing of methods or techniques required by the states for all operations. All study areas states derive baseline data requirements on a case-by-case basis. Some of the studies listed may not be required, depending on the ecological characteristics of the permit area and/or the availability of existing information.

adjacent areas.

DURATION, INTENSITY, AND REGIONALITY OF DATA COLLECTION. One year (four season) data collection is required (see Table 1). Only site-specific studies, including a one-mile buffer zone around permit area, are required.

DATA FORMAT AND AVAILABILITY. Data are submitted in permit applications on file with the PSC and OSM, depending on coal and surface ownership. PSC has no systematic compilation or clearinghouse for this information.

USERS OF DATA. Beyond PSC, there is little review or use by others.

REQUIRED MONITORING. Monitoring is not uniformly required by the PSC. Currently, monitoring programs are formulated on a case-by-case basis, depending on specific habitat reclamation requirements (e.g., replacement of woody draws or wetlands).

EVOLUTION OF DATA REQUIREMENTS SINCE 1977. The state has moved away from strictly counting wildlife species and numbers and has placed more emphasis on habitat descriptions, mapping, and eventual habitat replacement.

2.3.2 Montana

GUIDELINES. Montana has formal written guidelines (see Appendix C) that currently are being rewritten. These guidelines provide general guidance on objectives of the baseline studies, duration and intensity of studies, acceptable inventory methods, and baseline inventory plan submittal and approval. Detailed information on specific data collection methodologies is not supplied.

EMPHASIS OF REQUIRED STUDIES. Inventories of all wildlife species, determination of seasonal occurrence, and estimates of relative population densities of major and ecologically important species are required. Information on habitat types, delineation of habitats, and species utilization of habitats also is required.

REQUIRED STUDIES. Studies required by the Department of State Lands (DSL) are either determined on a case-by-case basis or are based on the current guidelines. Emphasis on field studies for specific species groups may be reduced by the DSL depending on existing information and previous research in the area. The Reclamation Division of the DSL must approve study design before implementation. Also, provisions must be made to expand the approved study program if the DSL indicates that a need is identified by baseline studies (see Table 1).

DURATION, INTENSITY, AND REGIONALITY OF DATA COLLECTION. One year (four season) data collection is required (two winter seasons preferred). DSL requires a minimum field time during baseline studies of one biologist on-site for one year (assuming a 5-day work week) for large operations in areas not studied previously. Usually, only site-specific studies are required, including a two-mile buffer zone around the disturbance area. If unique habitats are present, studies must assess the extent of these habitats on adjacent lands.

DATA FORMAT AND AVAILABILITY. Data are submitted in permit applications which are on file with either DSL and/or OSM, depending on coal and surface ownership. Annual monitoring reports also are submitted to DSL and OSM. Occasionally, data are incorporated into Montana Department of Fish, Wildlife, and Parks technical reports. The U.S. Fish and Wildlife Service (USFWS) maintains a limited compilation of raptor data, but otherwise there is no systematic compilation of, or clearinghouse for, wildlife permit information.

USERS OF DATA. Some consultants will use data from adjacent mines to develop wildlife information for their client's mine. As noted above, DFWP and USFWS also occasionally use these data. No other users were identified.

REQUIRED MONITORING. Monitoring, using methods similar to baseline data collection methods, is required for the life-of-mine until reclamation is considered complete by the DSL. During monitoring, aerial surveys are reduced to one per month, and minimum field time required is 100 man days per year. Objectives of monitoring are: 1) to compare wildlife population trends and indices to those measured on control areas and on areas prior to mining to assess the adequacy of habitat restoration and 2) to analyze the effects of mining on the ecology of the area.

EVOLUTION OF DATA REQUIREMENTS SINCE 1977. Wildlife regulations are more organized and consistent in addressing basic information needs. There is also more tailoring of information requirements to individual cases and their unique information needs. At present, less emphasis is placed by the DSL on monitoring and more emphasis is placed on reclamation specifically for wildlife and use of pre-mining data to develop success evaluations.

2.3.3 Wyoming

GUIDELINES. Wyoming has formal written guidelines available (Guideline No. 5, see Appendix C) that provide general guidance on baseline information, seasonal sampling, data analysis, mitigation and reclamation plan information, and reporting format requirements. The guidelines also provide information on acceptable data collection techniques for species groups. The guidelines are specific regarding data required and acceptable methodologies, but the guidelines stress that not all study and information requirements may be necessary for all operations. In some cases, operators may use or reference current existing information collected from adjacent areas in lieu of collecting new data. Although the guidelines are not mandatory, alternate methods should be approved by the Deparatment of Environmental Quality (DEQ) or the Game and Fish Department.

In addition to Guideline No. 5, the state has written specific guidelines for conducting raptor nesting surveys. The state requests, but does not require, that researchers use the Game and Fish Department standardized raptor nesting survey and wildlife observation forms.

EMPHASIS OF REQUIRED STUDIES. Determination of distribution, relative abundance, and habitat affinity of game species, state sensitive species, raptors, and threatened or endangered species is stressed. The state also emphasizes habitat classification, delineation and mapping, including both vegetation and physical features.

REQUIRED STUDIES. Study requirements are determined on a case-by-case basis in consultation with DEQ and the Game and Fish Department.

Acceptable data collection techniques are summarized by species group in Table 1).

DURATION, INTENSITY, AND REGIONALITY OF DATA COLLECTION. One year (four season) data collection is required. Seasonal surveys vary depending on species group (see Table 1). Only site-specific (permit area plus two-mile buffer zone) studies are required. A cooperative study by the Wyoming Game and Fish Department and coal operators on pronghorn in the Powder River Basin is the only regional study in the state. Some raptor studies conducted by coal operators have extended beyond required study area boundaries.

DATA FORMAT AND AVAILABILITY. Data are submitted in permit applications which are on file with DEQ and OSM, depending on coal and surface ownership. Annual monitoring reports also are on file at these offices. The Wyoming Game and Fish Department has compiled available wildlife information on regional wildlife resource maps in the past for the entire state; however, these maps have not been updated since 1981. Mapped information focuses primarily on game species, furbearers, state sensitive species, and threatened and endangered species. The Game and Fish Department encourages researchers to use their standard Wildlife Observation Form so that data can be entered easily in Game and Fish Department computers. This information is used to update Game and Fish Department wildlife resource maps. However, the forms are not used consistently and, in some cases, may not be compatible with study methodologies.

USERS OF DATA. Operators will use data from adjacent mines occasionally, but not often. The USFWS compiles and summarizes raptor data from mines in the state which are impacting or manipulating nests and has this information on file.

REQUIRED MONITORING. There are no across-the-board requirements; however, monitoring of big game, upland game, raptors, and threatened or endangered species is usually required.

When performed, monitoring usually is initiated by operators in consultation with the Game and Fish Department and DEQ to address specific wildlife concerns or habitat reclamation practices (e.g., monitoring of small mammal populations to demonstrate reclamation success, nesting of golden eagles on a highwall, etc.).

EVOLUTION OF DATA REQUIREMENTS SINCE 1977. The state is placing more emphasis on description and delineation of habitat and less on species inventories and population estimates. The state also has reduced data requirements for nongame species and species not protected by state or federal statute, especially where existing information from adjacent similar habitats is available. Large isolated mines proposed for new areas may still have to implement a full Guideline No.5 study, however.

2.3.5 Colorado

GUIDELINES. The Colorado Division of Wildlife (CDOW) has informal guidelines available on request. The guidelines identify pertinent data sources and provide general guidance for development of fish and wildlife baseline information and mitigation plan application sections. General requirements for data on habitat and species occurrence also are outlined. Specific data collection techniques are not discussed.

EMPHASIS OF REQUIRED STUDIES. Primary emphasis is on delineation and mapping of habitat, including special habitat features, and on use of the permit area by game species, species with stenotopic habitat requirements, state sensitive species, and threatened or endangered species.

REQUIRED STUDIES. Studies required for a particular operation are formulated on a case-by-case basis in consultation with the Colorado Mined Land Reclamation Division (CMLRD) and the CDOW. Acceptable data collection techniques are summarized by species group in Table 1.

DURATION, INTENSITY, AND REGIONALITY OF DATA COLECTION. One year (four season) data collection is required. Seasonal surveys vary depending on species group (see Table 1). Usually, only site-specific studies are required. Habitat mapping must extend at least 0.25 mile beyond the permit area boundary. There have been two instances where more than site-specific baseline information has been required. One operator currently is conducting an elk telemetry study that addresses, in part, regional movement of elk (see Section 3.6). Another study, which was not completed because the operation was not developed, involved a regional assessment of sage grouse habitat requirements and habitat enhancement for sage grouse in the North Park region of Colorado.

DATA FORMAT AND AVAILABILITY. Data are available only in permit applications and annual monitoring reports on file with either the CMLRD or OSM, depending on coal and surface ownership. The CDOW occasionally uses this data to update its Wildlife Habitat Inventory System, a computerized data bank of wildlife habitat and geographic information. Information contained in this system consists primarily of regional mapping of seasonal distribution and movement data for game, legally protected, furbearing, and other species. This information is available to the public upon written request.

USERS OF DATA. Aside from the initial review of permit application data by CMLRD or CDOW personnel, this information is seldom used by others. The Colorado Nature Conservancy has reviewed some of this information to compile data on state sensitive and threatened or endangered species. In addition, the Northwest Colorado Consortium (a cooperative effort between Colorado Universities and the CDOW funded by the BLM) has compiled wildlife data for Northwest Colorado from a variety of sources, including coal mining operations, in an effort to develop a model to predict the regional effects of shale oil development on wildlife populations of the area. The data collection phase of this study is finished but the modelling effort has not been completed.

REQUIRED MONITORING. No monitoring is formally required. Specific monitoring requirements are developed to address unique wildlife concerns or habitat reclamation practices associated with a particular mine operation.

EVOLUTION OF DATA REQUIREMENTS SINCE 1977. The state has always emphasized delineation and description of habitat. There has been a de-emphasis on studies for nongame species, and on other data that are seldom used for impact assessment or mitigation formulation. Colorado has found that for some species groups, such as small mammals and songbirds, separation of man-induced effects from observed natural variation has been impossible.

2.3.6 New Mexico

GUIDELINES. New Mexico has no formal written guidelines but intends to develop guidelines in the future.

EMPHASIS OF REQUIRED STUDIES. Studies required by the Mining and Minerals Division (MMD) and the Department of Game and Fish emphasize the characterization of pre-mining habitat conditions and quantitative data for all species groups, particularly those species felt to be in greatest jeopardy from mine development.

REQUIRED STUDIES. Studies and data requirements are determined on a case-by-case basis in consultation with MMD and the Department of Game and Fish with some review and input from the USFWS. Acceptable data collection techniques are summarized by species group in Table 1.

DURATION, INTENSITY, AND REGIONALITY OF DATA COLLECTION. When specific surveys are recommended one year (four season) data collection is required. Types of seasonal surveys vary depending on species group (see Table 1). Requirements for regional data collection depends on potential impacts and the species of wildlife to be impacted.

DATA FORMAT AND AVAILABILITY. Data are available only in permit applications which are on file with either MMD or OSM, depending on coal and surface ownership. Operators occasionally submit separate monitoring reports to MMD. MMD hopes, at some future date, to compile information into an organized data base.

USERS OF DATA. MMD, Game and Fish, and USFWS personnel review data when a permit application is filed. Other than this, data are seldom used except for occasional review by environmental groups.

REQUIRED MONITORING. No monitoring is formally required. When necessary, monitoring programs are determined on a case-by-case basis in consultation with the MMD and the Department of Game and Fish.

EVOLUTION OF DATA REQUIREMENTS SINCE 1977. The Department of Game and Fish has evolved from an agency whose concerns were only for those species of wildlife that had "consumptive" value to an agency that views all species of wildlife as being important. This change is reflected in recent recommendations for baseline data requirements for collection of quantitative data for all species groups.

2.4 Wildlife Baseline Data and Collection Methodologies

Wildlife baseline data presented in surface coal mine permit applications are obtained either from existing information sources or, more typically, from field studies designed to satisfy specific information needs. Field studies for baseline data collection are conducted primarily by biological consultants contracted by mine operators or by the biological staff of the mining company. Occasionally, university researchers are used by mine operators for special research programs. In some instances, cooperative studies between the mine operator(s) and the USFWS or state game and fish agency are developed to address special research topics. These data are usually presented in narrative form, or as maps, data tables, charts, or graphs.

Narrative descriptions are typically used to provide general background information regarding habitat and species occurrence within the permit area. Mapping is used to illustrate data on location and extent of habitats, big game ranges and seasonal distributions, and locations of key habitat features such as raptor nest sites and upland gamebird breeding grounds. Numerical or quantitative data (relative abundance, diversity indices, population estimates or counts) collected in the field for permit area wildlife species are usually summarized in table, graph, or chart format in the permit application. Examples of typical mapped, numerical, or quantitative data are presented as Figures 1 through 4.

2.4.1 Existing Information

Sources of existing information, used to satisfy permit application wildlife data requirements, can be classified into two general categories: 1) published literature and permit applications or monitoring reports and 2) wildlife agency data compilations, mapping, and reports. In general, data from the literature and adjacent area mine permit applications are used by operators or their consultants to obtain information on habitat and aspects of the life history requirements of wildlife species present in the area of interest. Sources of state and Federal wildlife agency information include state game and fish agencies, the USFWS, and BLM. The state game and fish agencies have published a variety of species life history reports,

PELLET GROUP SURVEY RESULTS

Habitat	Pellet Groups Observed	
	Deer	Elk
Valley Sagebrush	11	29
Juniper	162	
Valley Sagebrush/Valley, Dry-Slope Mixed Shrub (lower canyon)	151	1
Valley, Moist-slope Mixed Shrub	38	72
Valley, Dry-slope Mixed Shrub	10	98
Bottomland Shrub (total 2 transects)	15	58
Valley Riparian	2	7
Plateau Sagebrush (total 2 transects)	6	1
Plateau Mixed Shrub (total 2 transects)	63	
Aspen		23
Conifer	30	37

Figure 1 - Example of Big Game Pellet Group Data Submitted in Permit Application

BREEDING SEASON DENSITY INDICES AND RELATIVE ABUNDANCE OF BIRDS IN ASPEN HABITAT

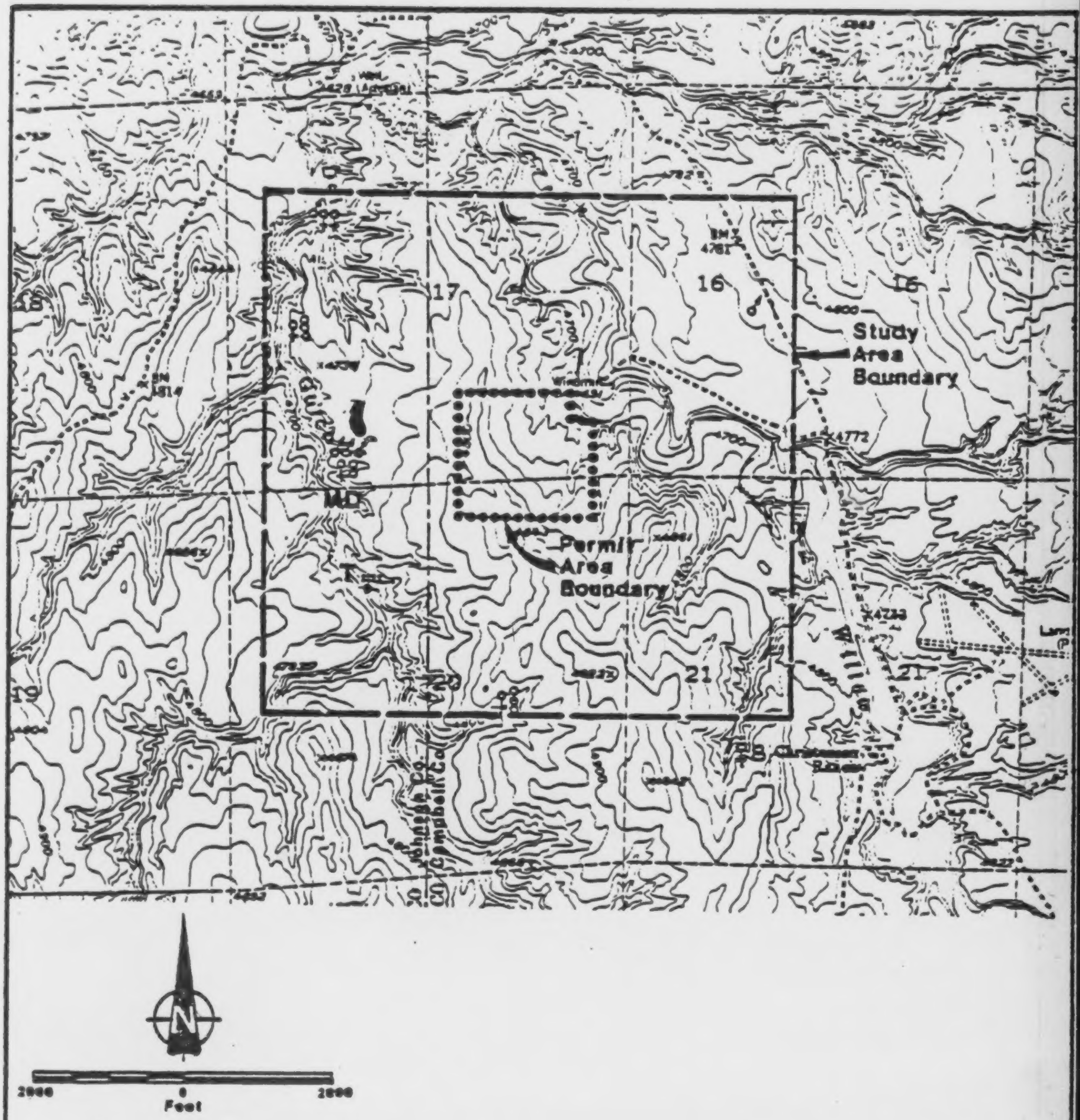
Species	Density Index (Birds/100 acres)	Relative Abundance (%)
Common flicker	7	3.8
Downy woodpecker	4	2.2
Dusky flycatcher	5	2.7
Violet-green swallow	3	1.6
House wren	55	30.0
American robin	17	9.3
Hermit thrush	10	5.5
Mountain bluebird	28	15.3
Warbling vireo	12	6.6
Orange-crowned warbler	1	0.5
Yellow warbler	8	4.4
Yellow-rumped warbler	10	5.5
MacGillivray's warbler	14	7.6
Black-headed grosbeak	7	3.8
Chipping sparrow	1	0.5
TOTAL	183	

Figure 2 - Example of Avian data Submitted in Permit Application

SUMMER RELATIVE ABUNDANCE OF SMALL MAMMAL SPECIES IN VARIOUS HABITATS

Habitat	Deer Mouse		Least Chipmunk		Golden-mantled Ground Squirrel		Southern Red-backed Vole		Long-tailed Vole		Sagebrush Vole		TOTAL
	No. Capt.	%RA	No. Capt.	%RA	No. Capt.	%RA	No. Capt.	%RA	No. Capt.	%RA	No. Capt.	%RA	
Valley Sagebrush	23	82	1	4	4	14							28
Valley, Moist-slope Mixed Shrub	14	36	11	28	14	36							39
Valley, Dry-slope Mixed Shrub	14	37	5	13	19	50							38
Bottomland Shrub	20	42			28	58							48
Valley Riparian	27	87	3	10	1	3							31
Plateau Sagebrush	15	63	8	33							1	4	24
Plateau Mixed Shrub	4	100											4
Aspen	3	12	8	31			7	26	8	31			26
Conifer	24	77	7	23									31
TOTAL	144		43		66		7		8		1		269
% Relative Abundance of All Individuals Captured		53		16		25		3		3		<1	

Figure 3 - Example of Small Mammal Data Submitted in Permit Application


17
16
16
18
19
20
21
21
BM 4761
4772
4700
4800
Study Area Boundary
Permit Area Boundary
MD
T
Johnson Co.
Campbell Co.
N
2000
0
2000
Feet

♂ ♀ ∘ Male, Female, and Fawn Antelope

⁝ Sage Grouse Hen and Brood

● Black-tailed Prairie Dog Town

MD Mule Deer

T Puddle with Immature Frogs

Figure 4 - Example of Mapped Data Submitted in Permit Application

primarily for game, state sensitive, and threatened or endangered species. In addition, some of the state game and fish agencies have published manuals describing baseline data collection methodologies and mitigation measures (see Appendix D for listing).

The CDOW and Wyoming Game and Fish Department have computerized data bases and mapping systems that provide regional information on habitats and species distribution for the states' wildlife resources. This information is valuable to operators for initial determination of the presence of threatened or endangered, game, and state sensitive species within a specific permit area. Mapped information is publicly available upon request to the appropriate state game and fish office. An example of Wyoming Game and Fish Department computerized mapping of wildlife information (with appropriate key) is provided as Figure 5.

Regional mapping of habitats and wildlife distributions also is available on BLM Unit Resource Analysis (URA) maps of public lands in each state. In addition, the BLM in Montana has compiled and published wildlife baseline information in reports for several Known Recoverable Coal Resource Areas (KRCRAs). Information presented in these reports focuses primarily on identifying wildlife species or resources pertinent to the U.S Department of the Interior's Land Unsuitability Criteria. The BLM uses this information to prioritize areas for future coal leasing and for development of special lease stipulations. Specific information such as locations of big game critical winter range, upland gamebird leks, and raptor nest sites are presented in these reports and can be valuable for use by operators in permit applications for coal mines proposed for the KRCRA.

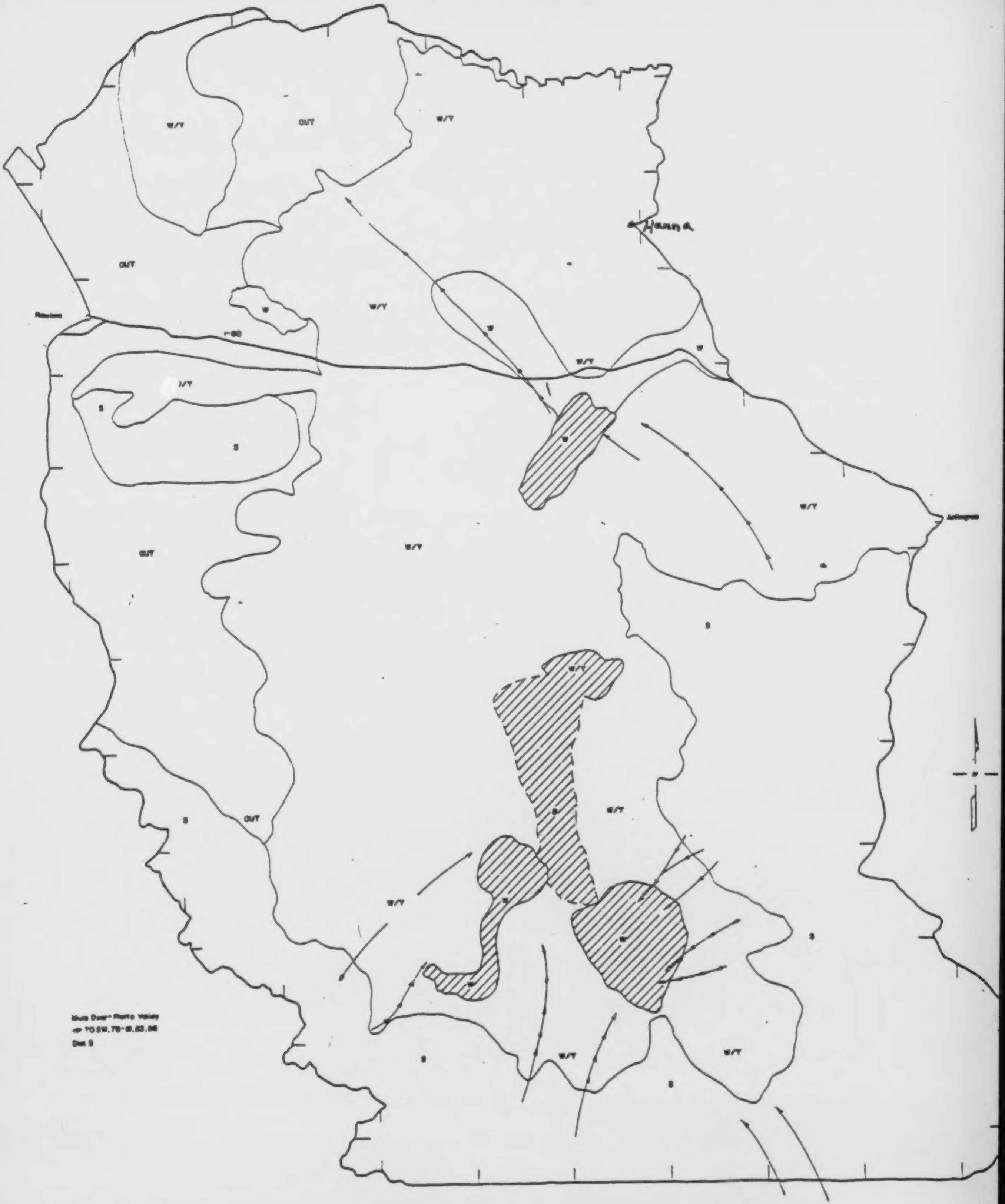

W/Y
OUT
W/Y
Hanna
OUT
W
W/Y
W
W/Y
W
Rawlins
I-80
S
S
W
W/Y
W/Y
OUT
S
W/Y
W
W/Y
S
OUT
W/Y
W
W
S
W/Y
S
W/Y
Mule Deer- Platte Valley

Figure 5 - Example of Wyoming Game and Fish Department Computerized Wildlife Information Mapping

GUIDELINES FOR MAPPING WILDLIFE DISTRIBUTION

TYPE	DESCRIPTION	SYMBOL
Summer	The general geographic area occupied by a migratory herd during summer months. (Approximately June 1 - October 31)	——— S
Winter	The general geographic area occupied by a migratory herd during winter months. (Approximately November 1 - May 31)	——— W
Migration Routes	Definable route followed during seasonal movements year after year. a. General area of movement b. Specific movement corridors	Mr →→— → → →
Parturition Areas	Geographic area consistently used for birth of young.	··—··— P
Breeding Areas	Geographic area consistently used for breeding by the majority of a population.	—·——· B
Display Areas	Sites consistently used by the male segment of game bird populations during courtship (e.g., strutting grounds, dancing grounds, drumming sites, etc.) a. censused b. uncounted c. abandoned	 ● ⊖ ⊗
Year-long	Geographic area occupied by all or a portion of the population for the entire year.	——— Y
Combination	Range where animals occur during more than one season.	——— S/Y ——— W/Y
Critical	That range that is present in minimum amounts and is the determining factor in the potential for population maintenance and/or growth. This will usually be represented by a winter concentration where most members of a population are forced during periods of maximum snow cover each year or where most members of a population are concentrated during periodic severe winters. The critical range may also be represented by late fall water source or other resources in short supply (e.g., cover for breeding, nesting, fawning, etc.). The degree of criticalness is related to a specific herd and is not related to the density of animals relative to any other herd.	▨

Figure 5 (Continued)

As mentioned previously, the USFWS compiles regional and site-specific information on federally-listed threatened and endangered species and also on raptors where they have been manipulated or impacted because of a specific mine operation. This information exists in USFWS files and format varies depending on species and extent of data available. They also have developed and published numerous manuals addressing wildlife baseline data needs, baseline data collection techniques, monitoring techniques, and mitigation measures for satisfying surface coal mining federal permit information requirements (see Appendix D for listing).

One additional source of regional wildlife information has been the Nature Conservancy Programs in each of the five study area states. Due to problems in funding, the future of these programs and their data compilations are uncertain. The principal objective of these programs is to collect and compile information on threatened or endangered species and on sensitive habitats for each state.

As discussed above, existing information primarily provides the operator with general background information regarding the wildlife resources of a particular area. Depending on the level of previous studies or inventory work on or near a specific permit area, site-specific information such as threatened and endangered species occurrence, raptor nest sites, upland gamebird breeding locations, and important big game range may be available. For most permit applications, some level of site-specific studies are required to address specific wildlife resources and supplement existing information. In some instances, site-specific studies have shown existing information to be in error. As described in

Section 2.3, compilations of existing information vary from state to state and from agency to agency. Where data are avalable in a computerized format, they are readily accessible. In other instances where data exist only in agency files or with local game and fish personnel, access can be more difficult.

2.4.2 Field Studies

A variety of acceptable techniques for field collection of wildlife baseline data can be used depending on targeted species groups and types of data required. Table 2 lists generally accepted survey techniques by species group, and the types of data that typically are collected using these techniques. This is not intended to be a comprehensive list of all techniques available or a list of required studies by all states; rather, it is a summary of the techniques used most often by researchers to address state or Federal information requirements. A brief description of methods used to implement specific survey techniques is provided in Table 3.

2.4.3 Techniques and Information Collected

Although a variety of accepted data collection techniques are available, the types of data collected are relatively standard. Most data can be classified into eight major categories: 1) species occurrence (including seasonal information), 2) species distribution, 3) relative species abundance or population estimates (including population size indices and species diversity values), 4) reproductive success, 5) food

Table 2

Wildlife Baseline Data and Survey Techniques

Survey Technique	Data Collected or Derived
Big Game	
Aerial Surveys	- Animal Distribution, Relative Abundance, Seasonal Occurrence, Population Size Estimates, Reproductive Success (Fawn/Doe or Calf/Cow Ratios), Concentration Areas, Habitat Preference
Vehicle & On-foot Surveys	- Animal Distribution, Relative Abundance, Seasonal Occurrence, Reproductive Success, Habitat Preference
Pellet Group Surveys	- Habitat Utilization, Population Size Indices and Trends
Browse Evaluation	- Habitat Utilization, Food Preferences, Habitat Condition
Stomach Contents or Pellet Analysis	- Food Preferences
Tagging/Radio-Tracking Telemetry Studies	- Home Range, Animal Movement, Population Size Estimates, Habitat Utilization
Medium-sized Mammals	
Aerial Survey	- Species Occurrence, Relative Abundance
Scent Station Visitation Survey	- Species Occurrence, Population Size Indices and Trends
Live Trapping	- Species Occurrence
Night Spotlight Survey	- Species Occurrence, Population Density Estimates
Strip Transects	- Population Density Estimates, Habitat Preference
Small Mammals	
Live or Snap-trap Traplines or Grids	- Species Occurrence, Relative Abundance, Population Size Estimates, Habitat Preference, Species Diversity
Prairie Dog Town Surveys	- Burrow Density, Colony Acreage
Raptors	
Aerial Surveys	- Species Occurrence, Nest Locations, Concentration Areas
On-foot and Vehicle Surveys	- Species Occurrence, Nest Locations
Nest Surveys	- Species Occupancy, Nesting Success and Production

Table 2 Continued

Survey Technique	Data Collected or Derived
Waterfowl and Other Waterbirds	
Ground Counts for Wetlands and Surface Water	- Species Occurrence, Animal Distribution, Relative Abundance, Seasonal Occurrence, Habitat Preference
Breeding Pair Counts	- Relative Abundance of Breeding Birds
Nesting Surveys	- Nesting Habitat
Brood Surveys	- Brood Rearing Habitat, Nesting Success, Production
Wetland Mapping and Evaluation	- Wetland Habitat Classification and Locations
Upland Gamebirds	
Aerial or Ground Surveys for Leks (Sage Grouse or Sharptailed Grouse Breeding Grounds)	- Lek Locations
Lek Breeding Bird Counts	- Lek Attendance, Indices of Population Size
Nesting Surveys	- Location and Extent of Nesting Habitat
Brood Surveys	- Brood Rearing Habitat, Production
Tagging/Radio Tracking Studies	- Animal Movement, Home Range, Habitat Utilization
Crowing Call Counts (Ring-necked Pheasant)	- Indices of Population Size
Crop Analysis	- Food Preferences, Species Occurrence
Roadside Surveys	- Indices of Population Size, Habitat Utilization
Songbirds and Others	
Variable Strip or Circular Plot Surveys	- Species Occurrence, Relative Abundance, Population Size Indices or Estimates, Habitat Preference, Species Diversity
Roadside Surveys	- Species Occurrence, Relative Abundance, Population Size Indices, Habitat Preference, Seasonal Occurrence
Reptiles and Amphibians	
Spring Night Call Surveys	- Species Occurrence, Relative Abundance
Miscellaneous Capture Techniques	- Species Occurrence, Relative Abundance
Wetland Searches and Seining	- Species Occurrence, Relative Abundance

Table 2 Continued

Survey Technique	Data Collected or Derived
Fish	
Seining	- Species Occurrence, Relative Abundance, Population Size Indices
Electroshocking	- Species Occurrence, Relative Abundance, Population Size Indices
Aquatic Habitat Description	- Habitat Quality, Classification
Aquatic Invertebrates	
Artificial or Natural Substrate Sampling, Bottom Sampling (Eckman Dredge or Surber Sampler)	- Species Occurrence, Relative Abundance, Species Diversity
Threatened and Endangered Species	
Aerial or Ground Winter Concentration or Roost Surveys (Bald Eagle)	- Locations of Roosts or Winter Concentration Areas
Winter Track or Sign Surveys (Black-footed Ferret)	- Species Occurrence
Night Spotlight Surveys (Black-footed Ferret)	- Species Occurrence
State Sensitive Species or Species of "High Federal Interest" (see applicable tehniques by animal group listed above)	- Generally - Species Occurrence, Habitat Utilization, Relative Abundance
All Species	
Incidental or Opportunistic Observations	- Species Occurrence, Distribution, Habitat Utilization, Relative Abundance

Table 3

Survey Techniques and Associated Methodologies[1]

Survey Technique	Methodology
Terrestrial	
Aerial Survey	- Slow fixed-wing aircraft or helicopter low level flights usually along standardized transects or conforming to specific habitats or topographic features. Record observatoins by species, numbers, and habitat.
Vehicle/On-foot Surveys	- Slow travel by vehicle or on foot along standardized survey routes. Record observations by species, number, and habitat.
Pellet Group Surveys	- Record number of big game pellet groups intercepted by standardized transect or contained within standardized plots within different habitats.
Browse Evaluation	- Determine by standardized evaluation methods the degree of hedging of shrub and tree species by big game.
Stomach or Crop Contents or Fecal Material Analysis	- Laboratory analysis of contents to determine plant and animal material ingested.
Tagging/Radio-tracking Telemetry Studies	- Trap and distinctly tag or attach radio transmitter to a sample number of animals. Record tagged animals by location and habitat when observed during other surveys. Locate radio transmitter animals on a regular basis through use of two or more receivers and triangulation. Plot locations by habitat and individual located.
Scent Station Visitation Survey	- Establish standardized number of scent stations along standard (USFWS) route. Stations consist of scent attractant in the middle of a circle of soft, smooth soil. Tracks of predator visitor recorded by species, station, and habitat.
Trapping	- Set live "Sherman" or "Havahart" type traps or snap traps in random patterns, clusters, line transects, or grids in suitable habitats. Captures recorded by species, number, and habitat. Various statistical techniques or models used to estimate population size of small mammals.

Table 3 (continued)

Survey Technique	Methodology
Night Spotlight Survey	- Slowly drive a predetermined route at night. With use of headlights and/or spotlight, record observations by species, number and habitat. Population indices calculated by dividing species numbers by acreage of corridor sampled by spotlight.
Strip Transects	- Slowly walk standardized transect in specific habitats and record species and numbers. Population indices calculated by dividing species numbers by acreage of corridor visually sampled.
Priaire Dog Town Surveys	- Estimate density of prairie dog burrows by various analytical techniques. Estimate acreage of town and plot extent and location of town on topographic maps.
Nest Survey	- Search all suitable habitat on foot with aid of binoculars or spotting scope. For inaccessible areas, search for nests by aerial survey.
Waterbird Surveys	- Make seasonal counts of all species and numbers occurring in all or a representative number of wetland or aquatic habitats. Record observations by survey area. For nest and brood surveys, search suitable habitat adjacent to wetlands or aquatic habitat and record nests and broods by location, species, and number.
Wetland Mapping and Evaluation	- Classify all wetlands by standard USFWS system. Map extent and location of all wetlands on topographic maps.
Lek Breeding Bird Counts	- Visit all known leks at least twice in early morning during spring breeding season. Record number of displaying males and females.
Crowing Call Counts	- Count and record number of pheasant crow calls in early morning for a set time period at standardized stops along a standardized vehicle route.
Variable Strip or Circular Plot Surveys	- Record species and numbers of birds by distance from observer along standardized transects or at predetermined points in all habitats. Population indices calculated for each species based on area sampled for that species.

Table 3 (continued)

Survey Technique	Methodology
Spring Night Call Surveys	- In appropriate habitats, record amphibian calls by species and number for a standard time period in the evening.
Black-footed Ferret Surveys	- Use current USFWS guidelines to search prairie dog towns for ferret track or sign. Use same guidelines for conducting night spotlight surveys.
Incidental Observatons	- During all field activities, record all wildlife observations by species, number, location, and habitat.
Aquatic	
Seining and Electro-shocking	- Sample aquatic habitats using seine or electro-shocking equipment. Record fish species captured by number and size.
Aquatic Habitat Description	- Measure various standardized physical parameters and classify habitat using established classification systems.
Bottom Sampling	- Using standardized sampling equipment, take sample of bottom substrate. Using sieves and washing, separate out aquatic invertebrates. Classify by species and number.
Artificial or Natural Substrate Sampling	- Scrape or sample by other means representative samples from surface of natural bottom substrate. Separate out aquatic invertebrates and classify by species and number. For artificial substrate, secure standardized plates beneath water surface. Leave for standard time period and then scrape surface and separate out aquatic invertebrates. Classify by species and number.

1/ See Appendix D for a listing of manuals that describe methodologies of these and other survey techniques in detail.

preferences, 6) habitat preference, 7) delineation of habitats, and 8) habitat quality.

Field personnel usually obtain information on species occurrence, species distribution, abundance, habitat preference, and reproductive success by direct observation of species and/or their definitive sign (tracks, scat, dens, nests, etc.). Habitat preference usually is inferred from data on species observations categorized by the habitat in which the observation occurred. Direct observation survey methods also are used to identify or locate portions of habitat or habitat features considered limiting or critical to the survival or maintenance of a particular species' population. Examples of these specific areas of habitat or habitat features include: raptor nest sites, critical big game winter range, sharp-tailed and sage grouse breeding grounds (leks), bald eagle winter concentration areas, and sandhill crane nesting habitat.

Methods used for direct observation are as varied as the habits of the species they are designed to document. The intensity and duration of effort required for these methods often are dependent on the inherent difficulties in observing a particular species, the sophistication of the techniques developed to serve this purpose, and whether quantitative or qualitiative data are required. Quantitative studies usually involve determination of relative-abundance estimates, population size indices, population trend information, and species diversity values. These kinds of data often are used as indirect indicators of habitat quality (i.e. the greater the number of animals and diversity of species, the better the habitat) or for comparisons of wildlife populations present in an area before and after mining disturbance and reclamation.

In the past, researchers have attempted to use intensive analytical techniques and data manipulations to calculate actual population size for wildlife species groups, especially songbirds and small mammals. Aside from counting highly visible animals in open habitats, such as pronghorn on flat grasslands, these attempts, as reported in research and monitoring reports and by state wildlife personnel, have been relatively unsuccessful. The inaccuracy of these techniques is due primarily to the natural variability and mobility of wildlife populations and to the difficulty in determining if observed variability is random or related to known or unknown environmental variables. The mobility of wildlife populations presents some unique measurement problems compared to methods traditionally used for most other technical disciplines (e.g., soils, vegetation). Because of these problems and the cost and/or practicality associated with implementing intensive population estimation procedures, actual population estimates are no longer attempted or required for most wildlife baseline studies. As less emphasis is placed on counting species and animal numbers, more emphasis is placed on determining habitat characteristics and quality, according to most state agency personnel.

Another problem related to attempting to strictly quantify wildlife populations is that quantitative measurement provides no indication of the relative health of individual animals or populations, and little information on their behavior. When this kind of information is needed or required, it is typically derived through qualitative observations and professional judgement.

Wildlife biologists use food preference studies to primarily determine what vegetation species are important for wildlife forage and should be planted in areas reclaimed for wildlife habitat. Methods used to determine food preferences primarily focus on big game and upland gamebirds. Typical procedures include direct observation of feeding animals, laboratory analysis of scat (fecal material), browse surveys (for big game), and laboratory analysis of both upland gamebird crop contents and big game stomach contents obtained from hunter or road-killed animals.

Habitat is delineated by transfer mapping from aerial photographs and by direct mapping and ground-truthing in the field. Habitat mapping is based predominantly on vegetation communities but also includes physical features such as cliffs, surface water, badlands, rough breaks, and rock outcrops.

In most cases, habitat quality is assessed through general observation of the condition of existing vegetation; the occurrence of important physical features such as surface water; topographic diversity; direct measurement of vegetational diversity, productivity, cover, and density parameters (see companion vegetation document); and the juxtaposition of floral communities (for edge effect). Except for the measurement of physical characteristics of aquatic habitat, quantitative descriptions or measurement of the physical attributes of terrestrial habitats have not been required or attempted beyond engineering maps of topographic contours and cross-sections. Measurement of physical factors such as stream gradient, number and average length of riffles, number and size of pools, shore gradient, and water quality parameters is used to classify and determine the quality of aquatic habitat. In addition, the presence of indicator aquatic invertebrate species such as mayfly and stonefly larvae provides an indirect measure of aquatic habitat quality.

Where critical or limiting terrestrial habitat or habitat features will be disturbed or removed by mining, more intensive studies and measurement of habitat parameters usually are required to obtain sufficient information to ensure these areas will be reclaimed to premining conditions. Typical studies required include more intensive soils and vegetation testing and measurement, detailed topographic descriptions, and radio-tracking telemetry studies of individual animals of a given species. Radio-tracking studies often are used in these instances to determine the extent of species dependence on a specific site or habitat feature, the areal extent of important habitats (based on known animal use), and species habitat utilization.

2.5 Impact Assessment

Analytical impact assessment techniques for predicting surface coal mining impacts to wildlife populations have not been found to be effective and are attempted infrequently, according to all state and federal regulatory, as well as industry, wildlife personnel interviewed. They also indicated that wildlife impact assessments for coal projects generally are made by intuitive professional judgement based on a knowledge of the operational aspects of the mining operation and of the ecological resources of the mine permit and surrounding area.

Regulatory authority and wildlife agency personnel use baseline data primarily to assess pre-mining habitat quality and to determine the need for mitigation planning to reduce expected impacts or restore or enhance reclaimed habitats for wildlife. Baseline data also provide regulatory agencies with a direct and an indirect measure of reclamation success by allowing general qualitative (and sometimes quantitative) comparisons between pre- and post-mining wildlife populations (see Section 2.6).

Difficulties in developing accurate impact assessment procedures are due primarily to the inability of the science of wildlife biology to measure wildlife populations accurately (see Section 2.4) or identify and segregate causes of all the variation exhibited by these populations. State agencies reported that some statistical and mathematical models have been developed to predict impacts to wildlife, but these models have not been particularly useful or successful.

The USFWS has developed and continually is upgrading it's Habitat Evaluation Procedures (HEP) program which provides a standardized approach for evaluating impacts to wildlife based on changes in habitat quality values (USFWS 1980a,b). With HEP habitat quality for selected evaluation species is documented with an index, the Habitat Suitability Index (HSI). This value is derived from an evaluation of the ability of key habitat components to supply the life requisites of selected species of wildlife. HSI values are obtained for individual species through use of documented habitat suitability models employing measurable key habitat variables. Over 80 HSI models have been published by the USFWS for use in applying HEP.

The HSI values are multiplied by area of available habitat to obtain Habitat Units (HUs) for individual species. These values are used in the HEP system for comparative purposes. For example, a comparison of HSI and HU values before and after a disturbance of existing habitats provides a standardized quantitative measure of the impact of wildlife habitat resulting from this disturbance.

As with any impact prediction methodology, HEP's ability to provide accurate projections of the magnitude of future impacts can be no better than the user's ability to predict future habitat conditions subsequent to disturbance. However, HEP does provide a quantitative mechanism for performing future projections on changes in habitat. In most cases, sufficient time has not elapsed for wildlife or reclamation professionals to judge the accuracy of their predictions regarding the suitability of postmining habitats for selected evaluation species.

Interviews with state and Federal regulatory and game and fish agency personnel indicated that a few attempts (in the Southeast U.S. and Texas) have been made to use HEP for projecting wildlife impacts related to surface coal mining disturbances. HEP has been used extensively for water development and similar projects where the extent of temporal and spatial habitat loss can be documented.

Other than professional intuitive assessments of impacts and attempts to develop impact assessment models, continued monitoring of wildlife populations or habitat has been the principal means of identifying and assessing mining impacts. In most cases, monitoring efforts have consisted of either a continuation of baseline data collection, usually at a reduced level of effort, to detect changes in wildlife distribution or population trends and to relate these changes to mining activity; or, in other instances, specific monitoring programs are developed to address a particular wildlife concern identified by the baseline studies. Examples of the types of studies that fall into the latter category include monitoring of: 1) raptor nests located in close proximity to mine disturbance, 2) road-killed big game species along mine access or haul roads, 3) sage grouse or sharp-tailed grouse leks located near mine areas, and 4) specific wildlife species that are displaced by habitat removal or disturbance.

Even with specific monitoring programs, mining-related impacts to wildlife populations often are difficult to assess quantitatively or qualitatively. In many cases, sufficient data are not available or cannot be collected (see Section 2.4.3) to determine if observed differences in population trends or distribution are directly attributable to surface-mining activity or to other known or unknown environmental factors. Even where mining activities result in the disturbance or loss of a habitat feature such as a raptor nest site, the impact to the individual birds and the overall raptor population usually remains unknown unless intensive (and expensive) radio-tracking telemetry studies are conducted to determine the fate of the displaced breeding raptors. Where definitive assessments of impacts have been necessary, extensive marking and radio-tracking studies have been the only means to demonstrate conclusively the extent and severity of impacts to specific wildlife populations.

Because of the inherent difficulties in monitoring wildlife populations (see Section 2.4) and assessing impacts to these populations, overall emphasis of many of the states' wildlife regulatory programs has shifted to the measurement or delineation of wildlife habitats and the replacement of those habitats during reclamation, based on the assumption that, if the habitat is replaced wildlife populations will return. Physical habitats are generally delineated based on physical features such as vegetation boundaries, shorelines, and other topographic features, while behavioral habitats (e.g., critical winter range) are delineated based on known behavior, observation, and knowledge of an animal group's biological life requirements. Physical features can be measured utilizing typical mapping, surveying, and photo-interpretation techniques.

2.6 Wildlife Mitigation Techniques and Success Determination

2.6.1 Mitigation Techniques

Techniques or practices employed to reduce or mitigate surface coal mining impacts to wildlife can be classified under four general categories: Avoidance, Operational, Offsite Enhancement, and Habitat Replacement/Enhancement. Table 4 lists selected mitigation techniques that have been or are being used by western surface coal mine operations. This table is not intended to be a comprehensive list of all techniques and methodologies, but rather a general summary of the more commonly employed measures. For more comprehensive information on these and other techniques, and on how they are implemented, the reader should refer to the selected list of references presented in Appendix D.

Table 4

Selected Mitigation Techniques Listed by General Category[1]

Avoidance

- Preserve Vegetation Patches[2]
- Preserve Important Habitat[2]
- Buffer Zones
- Temporal Avoidance During Critical Periods or Times
- Visual Barriers
- Protect Migration Corridors[2]
- Stagger Operations to Avoid Disturbing Large Tracts of Habitat Concurrently

Operational

- Restrict Speed Limits on Access and Haul Roads
- Compatible Location of Roads
- Underpasses/Overpasses for Roads and Conveyors
- Raptor-safe Powerlines
- Compatible Fence Design or Lay-down Fence for Big Game
- Employee Wildlife Awareness Programs
- Hunting & Fishing Allowed/ Not Allowed
- Prohibit Firearms in Vehicle
- Monitoring

Habitat Replacement/Enhancement

- Topographic Manipulation[2]
  - undulating surface
  - surface depressions
  - drainage reconstruction
  - microtopographic features
- Establish/Enhance Impoundments[2]
- Rock Piles/Boulders
- Transplant shrubs/Trees
- Establish Shrub Patches
- Establish Interspersion/Edge Concept with Vegetation Reestablishment
- Establish Shelterbelts/ Riparian Vegetation
- Direct Application of Topsoil
- Attain Shrub Density Standards[2]
- Brush Piles[3]
- Implant Dead Trees for Snags[3]
- Stream Habitat Reconstruction
- Improve Land Management Practices
- Nesting Structures[3]
- Leave/Modify Highwalls[2]
- Relocate Raptor Nests[2]
- Relocate Sage Grouse Strutting Grounds
- Special Studies/Research
- Perch Sites[3]
- Gallinaceous Guzzlers[3]
- Vegetation Species Selection

Offsite Enhancement

- Controlled Burning
- Fertilizing[3]
- Seeding
- Shrub Thinning or Crushing
- Elimination or Reduction in Livestock Grazing
- Impoundments[2]
- Strutting Ground Relocation
- Relocate Raptor Nests[2]

---

[1] For detailed descriptions and discussions of these techniques, please refer to the list of selected references in Appendix C.

[2] Legal, technological, and/or economic constraints limit the extent to which these practices may be employed.

[3] Temporary techniques that require maintenance beyond installation.

Avoidance mitigation techniques range from disallowing mining to preserving small patches of important habitat or maintaining or establishing visual barriers or buffer zones between mining operations and sensitive wildlife habitat. Avoidance measures also can be temporal in nature, for example prohibiting blasting near raptor nests during the breeding season or prohibiting mining through a sage grouse lek during the breeding season. Where temporal avoidance only postpones habitat removal during important wildlife seasonal activities, the benefits derived usually are short-term and do not mitigate the long-term effects of habitat loss. Avoidance of important habitats or patches of vegetation can be important for maintaining natural sources of wildlife and vegetation for reinvasion into reclaimed areas, but the importance of these areas as wildlife habitat during mining may be limited if the areas are small and isolated by large tracts of disturbed land. Operational, cost, and full coal recovery constraints often limit an operator's ability to avoid important habitats. In most cases, avoidance of habitat based on wildlife concerns only occurs as an incidental result of operational considerations or where the US Department of the Interior's Land Unsuitability Criteria (No. 9 through 15) are invoked.

Operational mitigation techniques may involve education or regulation of employees, or modifications in mine operations or mine plan structures to reduce the potential of direct mortality, harassment, or movement disruption impacts to wildlife. Many of these techniques are implemented to satisfy some of the more specific requirements of the SMCRA performance standards (30 CFR 816.97). Measures such as posting reduced speed limits (to reduce the potential for big game-vehicle collisions) or placement and design of roads, conveyors, or fencelines so as not to preclude wildlife movement are examples of operational mitigation measures.

Offsite enhancement of wildlife habitat may be used to offset projected wildlife impacts resulting from disturbance or removal of mine area habitats. Offsite enhancement measures usually focus on modifying habitats to increase their productivity or carrying capacity and their suitability for targeted wildlife species, usually those displaced by the mining operation. Relocation of raptor nests, establishment of impoundments, elimination of livestock grazing, and thinning of overly dense shrub stands are examples of offsite enhancement measures. Land use practices on adjacent areas and land surface ownership usually are the primary non-economic factors determining the extent to which offsite enhancement measures are implemented.

The greatest number of potential wildlife mitigation measures relate directly to habitat replacement or enhancement during reclamation. At a minimum, all mine operations give some consideration to wildlife in formulating planting and seeding mixtures for revegetation. Where the proposed primary post-mining land use for reclaimed areas is not wildlife habitat, additional wildlife habitat mitigation measures are often limited. Where wildlife habitat is the primary proposed land use, or in situations where habitats for state sensitive or legally-protected species will be disturbed, wildlife habitat replacement or enhancement measures become more involved and extensive. Examples of specific, more intensive measures implemented to replace or enhance wildlife habitat include: manipulation of post-mining topography to obtain diversity in landform;

planting of woody vegetation to provide wildlife food and cover; and attempts to relocate raptor nests or sage grouse strutting grounds to avoid loss by mining.

2.6.2 Mitigation Constraints

The extent to which many of these more intensive measures are implemented for wildlife often is determined by operational, economic, legal, or technological constraints (or by post-mining land use considerations). For example, legal, operational, and/or economic constraints may prevent an operator from returning land to conditions of undulating or broken terrain, even though topographic diversity is known to increase floral diversity and benefit wildlife.

The costs to implement many of the more intensive wildlife habitat mitigation measures are not well documented. In addition, cost-benefit ratios for different wildlife mitigation options are difficult, if not impossible, to derive due to the inherent difficulties involved with assigning monetary values to wildlife benefits. Where a post-mining land use is wildlife habitat legal constraints arise when wildlife habitat mitigation measures are at odds with SMCRA or state coal mining regulations governing the other technical disciplines. For example, leaving highwalls or permanent impoundments after cessation of mining are considered by nearly all wildlife agency personnel to be viable and highly beneficial wildlife habitat enhancement techniques where these features are demonstrated as feasible and ecologically beneficial. However, these enhancement techniques are often difficult to implement due to current regulations (which exist to protect other resources) regarding approximate original contour and the retention of permanent impoundments or undrained areas.

Technological or biological constraints on mitigation are related to the limited ability of state-of-the-art techniques to successfully identify and establish habitat components or features that are beneficial to wildlife or are essential to their survival. Emphasis of much of the current reclamation research is directed toward better and more cost-effective means of replacing habitat components such as woody vegetation, wetlands, or raptor nest sites. Other research has focused on obtaining a better understanding of the habitat requirements of state sensitive or threatened and endangered species, especially habitat that is considered essential or limiting to their survival.

2.6.3 Mitigation Planning

Formulation of wildlife mitigation plans for surface mine operations is usually done on a case-by-case basis. The mitigation measures chosen for the plan are based on a knowledge of the proposed operation, the budget of the operator, and the ecological resources of the permit area. The wildlife mitigation plan (Fish and Wildlife Plan) usually is developed by the operator's biological staff or by an environmental consultant, often in consultation with state regulatory and fish and game personnel. The degree of consultation varies between states and operators and also is related to the perceived severity of anticipated impacts to important wildlife species or habitats. Often the plan is modified based on regulatory review comments received prior to permit application approval. In cases where the plan does not satisfy guidelines or permit requirements established by the state regulatory authority prior to permit approval, special wildlife mitigation conditions may be appended to the permit. (Sometimes these conditions requiring specific baseline studies or mitigation practicies exist as stipulations on the leasing agreements with the land management agency.)

2.6.4 Mitigation Success Determination

All state agency personnel have reported that there are no regulatory standards, or bond release criteria, used to judge the success of wildlife mitigation measures. There are, however, numerous standards regarding revegetation reestablishment, topsoil placement, and water quality that relate directly to reclamation of wildlife habitat (see companion vegetation (Sections 4.4 and 4.5), soils (Section 4.5), and hydrology (Section 4.4) reports). Regulatory reviews for successful habitat replacement focus primarily on revegetation parameters. The lack of success standards specific to wildlife is due, in part, to the inherent problems associated with measuring mobile wildlife populations (see Section 2.4), and also to the fact that mitigation measures currently being implemented are at the most only 5 or 6 years old. In most cases, it is virtually impossible to exactly replace pre-mining vegetation communities during reclamation. At best, an early successional stage can be established, and it may take decades for this community to return to its pre-mining status (which may not be the most beneficial community with

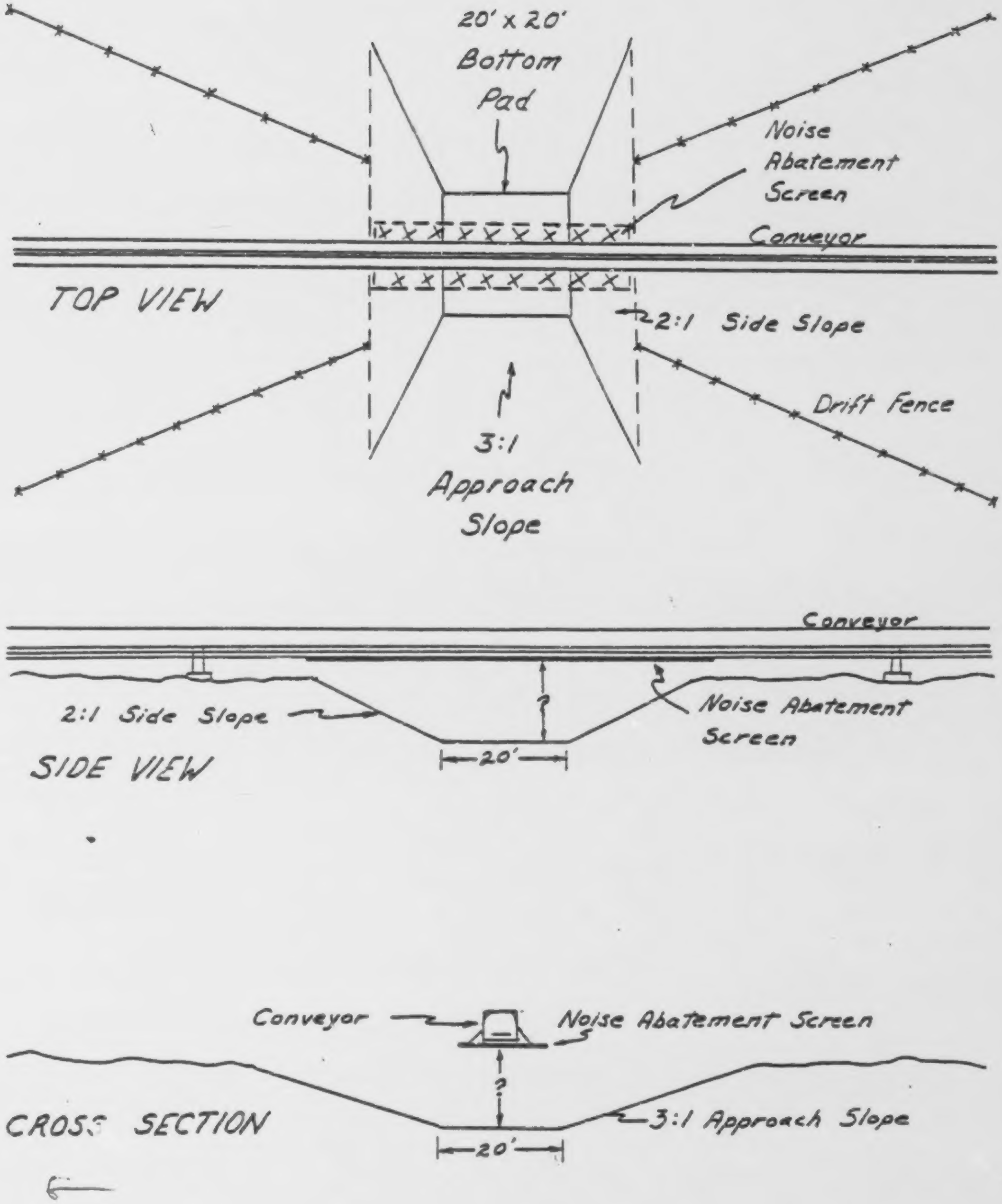
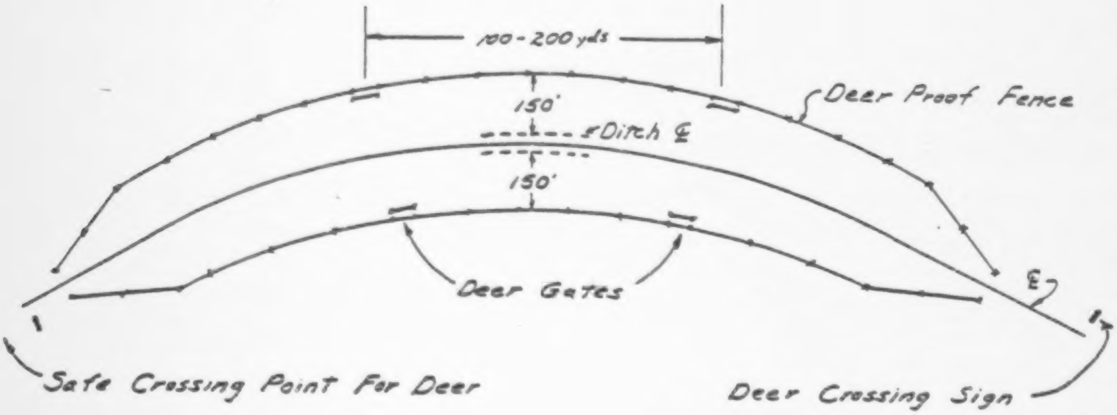

20' x 20'
Bottom
Pad
Noise
Abatement
Screen
Conveyor
TOP VIEW
2:1 Side Slope
Drift Fence
3:1
Approach
Slope
Conveyor
2:1 Side Slope
Noise Abatement
Screen
?
20'
SIDE VIEW
Conveyor
Noise Abatement Screen
?
CROSS SECTION
3:1 Approach Slope
20'

Figure 6 - Conveyor System Underpass Structure Design for Mule Deer Passage


100-200 yds
150'
Ditch ℄
150'
Deer Proof Fence
Deer Gates
℄
Safe Crossing Point For Deer
Deer Crossing Sign

Example Design For Deer Proof Fence Location
And Construction

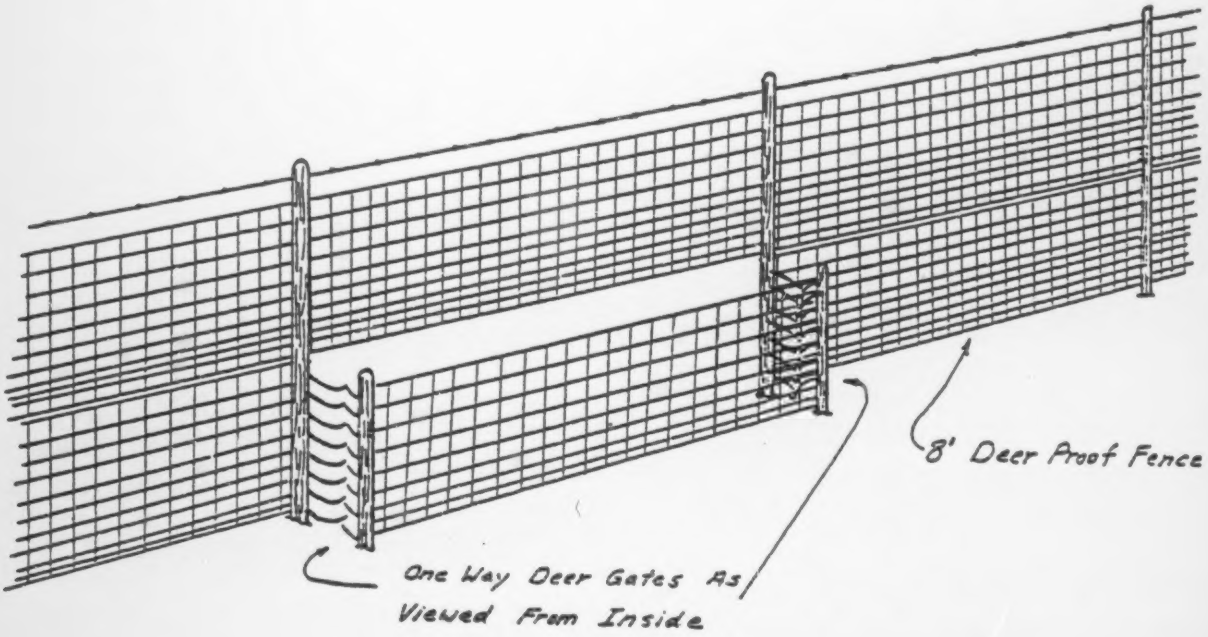

8' Deer Proof Fence
One Way Deer Gates As
Viewed From Inside

Figure 7 - Typical Deer-Proof Fencing with One-way Gates

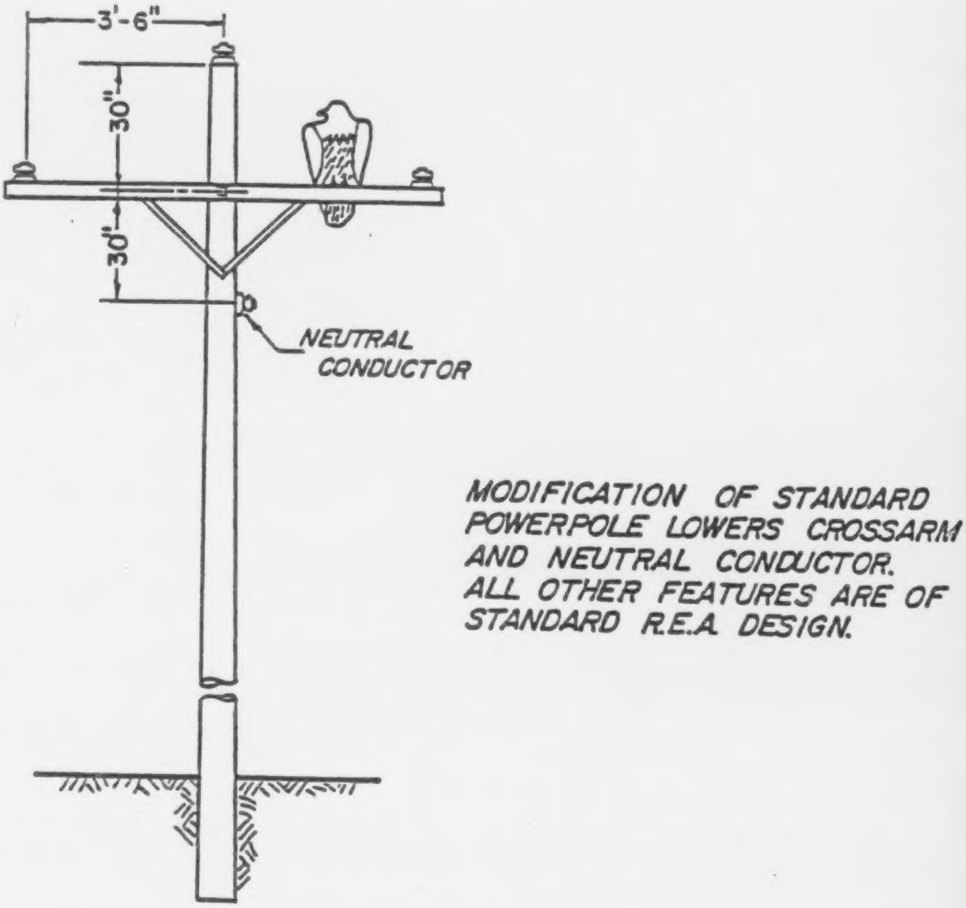

3'-6"
30"
30"
NEUTRAL CONDUCTOR
MODIFICATION OF STANDARD POWERPOLE LOWERS CROSSARM AND NEUTRAL CONDUCTOR. ALL OTHER FEATURES ARE OF STANDARD R.E.A. DESIGN.

Figure 8 - Example of Electrocution Proof Powerpole for Raptors

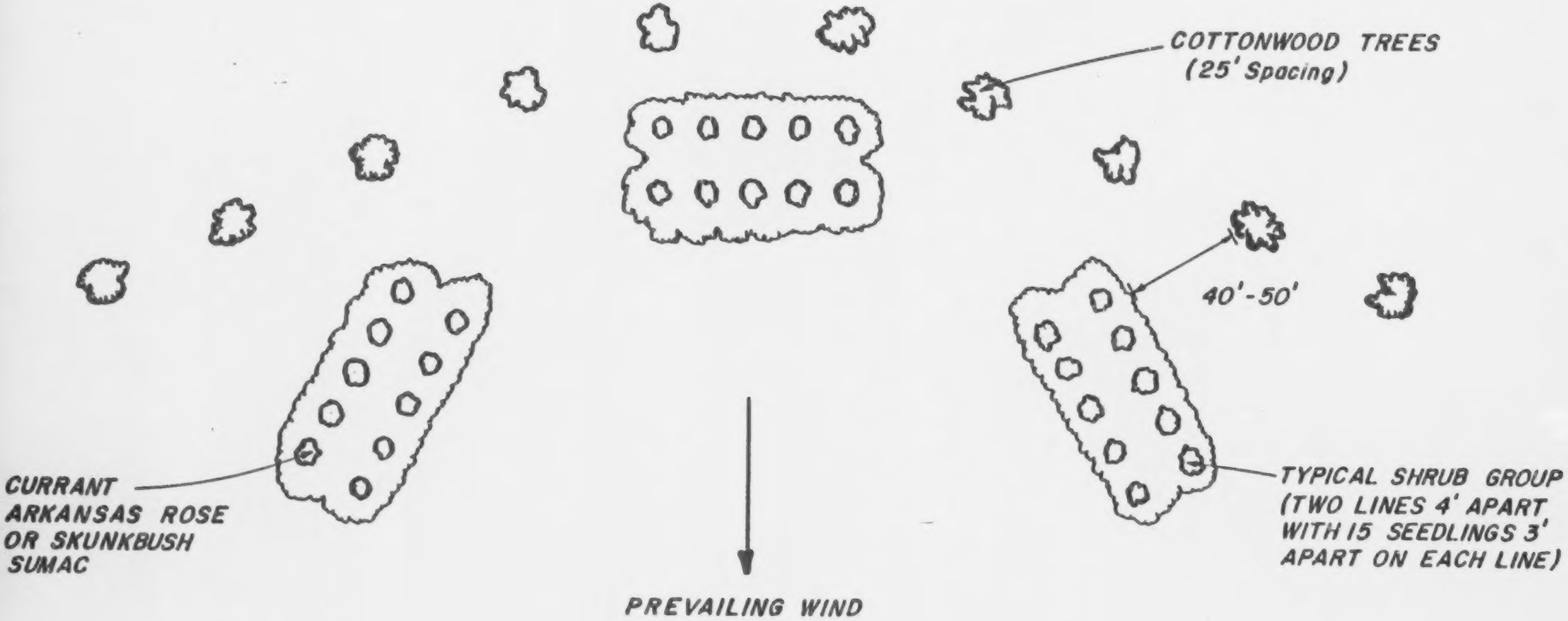

COTTONWOOD TREES
(25' Spacing)
40'-50'
CURRANT
ARKANSAS ROSE
OR SKUNKBUSH
SUMAC
PREVAILING WIND
TYPICAL SHRUB GROUP
(TWO LINES 4' APART
WITH 15 SEEDLINGS 3'
APART ON EACH LINE)

Figure 9 - Typical Tree/Shrub Planting for Wildlife Habitat Enhancement

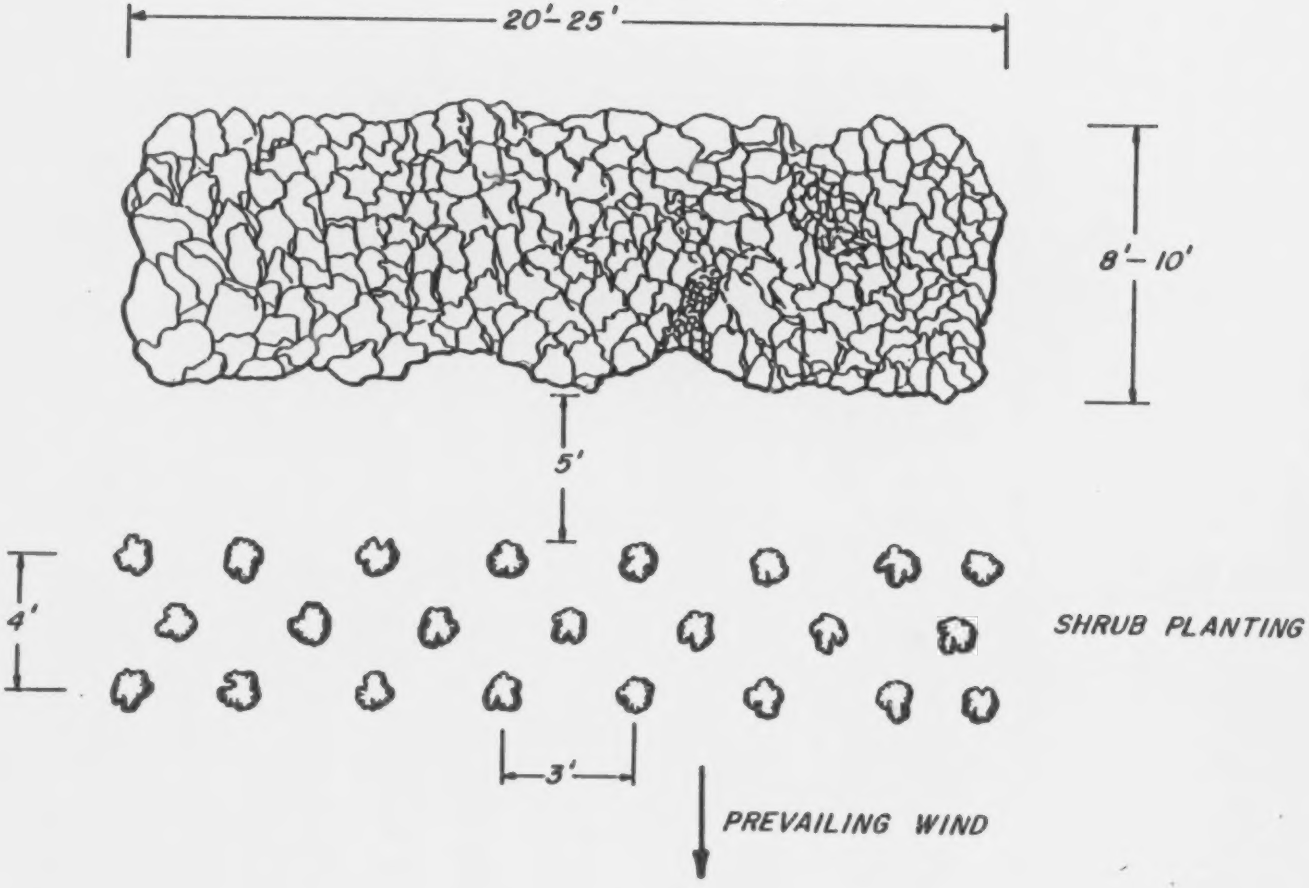

20'-25'
8'-10'
5'
4'
SHRUB PLANTING
3'
PREVAILING WIND

Figure 10- Typical Rock Pile Configuration for Enhancement of Wildlife Habitat

respect to wildlife, due to past management practices - for example, overgrazing).

Because wildlife populations are dependent on vegetation and other habitat features, post-mining wildlife populations also may take decades to return to similar levels of diversity and population density similar to those that existed prior to mining. It is also conceivable that wildlife diversity and density may exceed pre-mining levels in response to the early successional floral communities re-established after mining because early- to mid-successional floral communities can be better "producers" of wildlife than late-successional and climax communities. Although success standards for evaluating mitigation specific to wildlife are lacking, design standards are available for some of the structures and operational measures used to mitigate impacts to wildlife. Raptor-safe powerlines, range fencing that permits pronghorn passage, road underpasses and overpasses for wildlife, and artificial nest sites are examples of structures for which design standards are available (see Figures 6 through 10 for examples of these kinds of structures. The USFWS is currently working to develop design standards for raptor nest and highwall manipulations.

According to several regulatory and fish and game personnel, research is needed to determine design standards for many of the more commonly suggested habitat enhancement or replacement mitigation measures such as construction of shrub patches or rock piles. Intuitively and ecologically it generally is understood by wildlife professionals that many of these features are beneficial to wildlife, but minimum design standards for optimum establishment usually are not so obvious. Numerical parameters are needed to address questions such as: what is the best design for such features? what size is optimum? and where is it most desirable to establish mitigation features such as rock piles and shrub patches? Without proven numerical parameters or design standards it is difficult for operators to have confidence in suggested or stipulated wildlife habitat enhancement measures. It is even more difficult for the regulatory authority to evaluate compliance with respect to the wildlife mitigation plan.

The primary method used to determine success for wildlife mitigation measures is continued monitoring following baseline investigations or the initiation of specific monitoring procedures to address concerns identified by the baseline data. Where monitoring is a continuation of baseline data collection studies, techniques used are often the same, although usually at some lower level of effort, as those implemented for baseline studies. In instances where specific problems are identified and monitoring is required, implemented techniques are often more intensive than those implemented for baseline studies. When monitoring is required by the regulatory authority, the operator frequently must sumbit an annual report of the findings. These reports are most often filed along with the operator's permit application. Results of monitoring implemented at the initiative of the operator are frequently held and remain in the operator's files unless the operator feels the need to demonstrate a particular point to the regulatory authority.

Where design or success standards are lacking, determination of mitigation success by monitoring usually is based on comparisons of general wildlife trends, or utilization of habitat, and professional judgement. In some cases, such as continual use of a raptor nest, success or failure often is fairly obvious. As noted above in situations such as habitat replacement, success or failure often is not immediately obvious and may not be so for several decades. For this reason and also because of the problems discussed in this chapter relating to measurement of wildlife parameters, there are few regulatory requirements that make any bond release contingent on the success of wildlife mitigation measures, other than those relating to habitat replacement by revegetation.

3.0 CASE STUDIES

3.1 Chapter Introduction

The objectives of this section were to analyze: data collection techniques; data collected; specific methodologies used to assess and mitigate wildlife impacts; and the procedures and criteria used to evaluate the success of mitigation techniques for eight selected case studies. Case studies were chosen from all five western study-area states. The primary intent of the case study analysis is to amplify points made within Chapter 2.0 regarding data collection, impact assessment, mitigation procedures, and the success of these efforts. Selection of case studies was based on the following mine features: 1) special wildlife concerns, unique wildlife related-problems, or exemplary wildlife conditions; 2) specific criteria such as geographic location, topography, land use, endemic vegetation, soils, and other general characteristics which have an effect on reclamation for wildlife; and 3) whether the mine also was being studied by OTA contractors in other disciplines, thereby allowing interdisciplinary comparison. Table 5 identifies selection criteria and other pertinent attributes of the eight case studies used in this analysis.

Selected mines were analyzed through review of existing permit applications and associated documents on file with the Western Technical Center (OSM) or with appropriate state agencies. In addition, either personal or phone interviews were conducted with the appropriate individuals at each mine to obtain further information on: 1) how data were being used; 2) how impacts were assessed; 3) how mitigation techniques were

TABLE 5

Selection Criteria For Wildlife Discipline Case Studies

STATE MINE	Use By Other Disciplines	Wildlife Concerns/ Problems	Unique Habitat Features	Land Use	Physiography	Age of Mine	Endemic Vegetation
NORTH DAKOTA							
MINE A	Yes All Three	Wetland/Pothole Restoration, Waterfowl, Upland Game Breeding Habitat	Wetlands, Woody Draws	Agriculture, Grazing, & Wildlife	Flat Glacial Plains	Circa 7 years	Cropland/Wheatgrass-Needlegrass Prairie
MINE B	Yes All Three	Woody Draw Habitat, Upland Game, Big Game	Woody Draws	Agriculture, Grazing, & Wildlife	Rolling to Flat Terrain	Circa 40 years	Wheatgrass-Needlegrass
MONTANA							
MINE C	Yes Two Others	Sage Grouse Strutting Grounds Fisheries Habitat, Extensive Big Game Range Studies	Riparian Shoreline	Grazing	Rolling Terrain	13 years	Grama-Needlegrass Wheatgrass/Sagebrush Steppe
WYOMING							
MINE D	No	Highwall Experiment, Raptor Nesting	Rim Rock	Grazing, Wildlife	Rolling/ Broken Terrain	13 years	Sagebrush Steppe

TABLE 5 (Continued)

STATE MINE	Use By Other Disciplines	Wildlife Concerns/ Problems	Unique Habitat Features	Land Use	Physiography	Age of Mine	Endemic Vegetation
COLORADO							
MINE E	Yes All Three	Elk Calving Grounds and Winter Range, Raptor Nesting, Sage Grouse, Sandhill Cranes	Aspen & Mountain Brush	Agriculture, Grazing, Wildlife	Steep to Rolling Terrain	23 years	Aspen, Mountain Brush, Sagebrush Steppe, Cropland
MINE F	Yes Two Others	Big Game Winter Range Raptor Nesting	Mountain Brush	Agriculture, Grazing, Wildlife	Steep to Rolling Terrain	4 years	Mountain Brush, Sagebrush, Cropland
NEW MEXICO							
MINE G	Yes One Other	Big Game Range With Adjacent Lands Intensively Managed For Wildlife Habitat/Recreation	P-J, Mixed Conifer, Oakbrush	Recreation, Wildlife	Steep to Rolling, Broken	Circa 20 years	P-J, Mixed Conifer, Oakbrush, Meadows
MINE H	Yes All Others	None		Grazing	Flat Terrain	12 years	P-J, Saltbush-Greasewood

implemented; and 4) how well mitigation efforts were working with respect to their intended function.

It should be pointed out that all mines investigated in this analysis which have been granted a permit, have committed to compliance with applicable wildlife performance standards as required by the Federal Regulations (30 CFR 816.97) (e.g., all transmission lines will be built in a manner which prevents electrocution hazard to raptors; wildlife will be excluded from concentrations of toxic materials; persistent pesticides will not be used; etc.) Discussion of these mitigation efforts will not be repeated for each case study unless something unique can be offered by the discussion. However, where a case study exhibits extraordinary efforts with respect to these performance standards, more detail is presented.

3.2 Mine A

3.2.1 Description of Appropriate Site Characteristics and Information

Mine A is located in central North Dakota and began producing coal in 1976. Lignite coal is mined by a dragline operation and trucked to a nearby conveyor that transports the coal to a local powerplant. The predominant premining land use was cropland, with a relatively small amount of native rangeland and a very small amount of wildlife habitat as additional uses. Cropland is the primary targeted post-mining land use with rangeland and wildlife habitat acreages to be returned as well. The most important wildlife habitat disturbed by mining and targeted for restoration is "prairie pothole" wetland.

The climate of the area is classified as continental with a considerable variation in both diurnal and seasonal temperatures. Average annual precipitation is between 16 and 17 inches and the usually westerly winds average between 9 and 11 miles per hour. The soils of the mine area are deep and of glacial origin. The predominant vegetation community is classified as cropland. Major crops include hard red spring wheat and durum. A small, yet significant, portion of the mine area consists of native prairie community containing occasional prairie pothole wetlands that exhibit a wide variety of floral species depending on water levels. Woody draws are present in the area but will not be affected by mining during the current permit term.

3.2.2 Focus of Wildlife Concerns

Prior to mining, most of the surface was managed intensively for agriculture. Both the areal and historical extent of this activity has long since precluded many of the native wildlife species typically found in undisturbed northern prairies. However, at least a few of the displaced species have been replaced by more agriculturally tolerant wildlife, such as white-tailed deer and ring-necked pheasant. White-tailed deer occasionally are seen near wooded areas or at the margins of agricultural fields but are not present as large populations. Several species of upland gamebirds are found in the area and include: sharp-tailed grouse, ring-necked pheasant, gray partridge, and mourning dove. Waterfowl are common summer residents and migratory visitors to the scattered wetlands.

A few species of raptors inhabit this area, but only owls and marsh hawks are known to nest on-site. Game fish are not known to inhabit any of the area's wetlands, and no threatened or endangered species have been observed on the permit area.

Because many native wildlife species already have been displaced by agricultural activities and resident species are generally tolerant of man's activities, the wildlife concerns at Mine A are focused on preservation of what little natural wildlife habitat that still exists. Primary emphasis is directed toward the restoration of "prairie pothole" wetlands and native rangeland following mining, and avoidance of woody draws during mining. Concern has been generated, however, that unlike rangelands, little is known about restoration of wetlands. As a result, many entities (including: Mine A, NDPSC, North Dakota Game and Fish, and USFWS personnel) are very interested in developing sound reclamation technologies to replace wetlands lost to mining. The replacement of wetlands as an important wildlife habitat is founded on reclamation technologies related primarily to other disciplines - soils, overburden, hydrology, and vegetation. Therefore, most information pertinent to this topic is presented in this report's companion documents (Vegetation Report - Section 3.3 and Hydrology Report - Section 3.3, soils for this operation are not presented in the Soils Report).

3.2.3 Methods and Data

Baseline data collection for wildlife occurred during 1979 and 1980 and involved comprehensive studies over a one-year period. Studies were performed in direct response to the PSC's and North Dakota Game and Fish Department's requirements. Data were required, by habitat type and usually by season, for all species groups known to exist in the mine area. Special emphasis was placed on waterfowl data collection and the evaluation of the "prairie pothole" wetlands within the life-of-mine boundary since protection of wetland habitats is specified in the Federal Performance Standards (30 CFR 816.97(d)(5)(10)). The methodology used and data obtained are summarized in Table 6.

Most data collected were used primarily to satisfy permitting information requirements, and certain information (waterfowl utilization, wetlands classification, aquatic data, etc.) was used to formulate wetland restoration plans and monitoring procedures. According to Mine A personnel, both wetland-related data and, possibly, other wildlife data will be used at some future date to perform a detailed impact analysis and mitigation success determination of Mine A's replacement of wetlands and indigenous wildlife. However, both mine and regulatory personnel believe that future baseline efforts should concentrate on the evaluation of habitats and special characteristics of important habitats, rather than on extensive inventories of wildlife populations.

3.2.4 Impact Analysis and Monitoring

Baseline data were used as input for making intuitive assessments of impacts due to Mine A development. Neither statistical analyses nor other mathematical efforts were used. Analyses being conducted for Mine A include evaluation of expected versus observed animal distributions and

TABLE 6

Wildlife Methods and Data Collected for Species Groups at Mine A

Species Group Methods	When Used	Data Collected
Big Game		
Aerial Survey	B	Relative Abundance, Distribution, Habitat Affinity, Reproductive Success, Concentration Areas
Medium-sized Mammals		
Aerial Survey	B	Species Occurrence, Den Locations
Trapping	B	Species Occurrence, Relative Abundance
Small Mammals		
Trapping	B	Species Occurrence, Relative Abundance
Raptors		
Aerial Survey	B	Habitat Affinity, Nesting Sites
Ground Observation	B	Nesting Sites, Reproductive Success, Species Occurrence
Upland Gamebirds		
Crowing Counts	B	Species Occurrence, Relative Abundance
Breeding Survey	B,M	Leks, Relative Abundance
Production Survey	B	Brood Rearing Habitat, Reproductive Success, Relative Abundance
Incidental Sighting	B,M	Species Occurrence
Waterfowl and Shorebirds		
Migration Counts	B	Species Occurrence, Migratory Movement, Habitat Utilization
Breeding Surveys	B,M	Species Occurrence, Habitat Utilization, Brood Rearing Habitat
Production Surveys	B,M	Reproductive Success
Songbirds and Others		
Strip Transects	B	Species Occurrence, Relative Abundance, Habitat Affinity, Species Diversity

TABLE 6 (Cont.)

Species Group Methods	When Used	Data Collected
Qualitative Obs.	B	Species Occurrence, Habitat Affinity
Reptiles and Amphibians		
Incidental Sighting	B	Species Occurrence
Fish		
Seining, Gillnetting	B	Species Occurrence, Relative Abundance, Habitat Quality
Electro-Shocking	B	Species Occurrence
Aquatic Invertebrates		
Bottom Grab Samples	B	Species Occurrence
T, E, & Sensitive		
Incidental Sighting	B,M	Species Occurrence

B = Baseline Studies
M = Monitoring Studies

numbers; presence or absence of suitable habitat; and the ability of animals to adapt to man-caused stimuli. In addition, for wetlands, a monitoring program was established to collect data for future semi-quantitative evaluations of impacts and reclamation success determination (see Section 3.2.6).

The wildlife component of monitoring for wetlands consists of general observational surveys once per week through spring and summer and twice per month for fall and winter. These surveys are performed on undisturbed habitats, on disturbed areas being mined, and also on disturbed areas once they are reclaimed.

3.2.5 Mitigation Planning

Wildlife mitigation at Mine A consists mainly of habitat-related efforts rather than techniques directed at specific life requirements of individual species or groups, such as construction of nesting boxes. Wherever possible, avoidance of important habitats (wooded areas and wetlands) is practiced. It is also the intention of the mine operators not to disturb woody draws in the path of future mining. If a mine facility, such as a sedimentation pond, unavoidably disrupts woody habitat, the mine operator has committed to replacement of the disturbed habitat on an "acre-for-acre" basis. This commitment also has been made for wetlands. Where certain wetlands were necessarily lost to the mining operation, reclamation efforts have proceeded toward their replacement. Reclamation of the third most important habitat, native prairie, occurs on as close to an "acre-for-acre" basis as possible.

3.2.6 Success Determination Methods

Mine A is one of the few operations where methods for wildlife mitigation success determination are being developed. These success standards focus on wetland restoration and involve an interdisciplinary assessment that includes monitoring of wildlife utilization of the newly-established habitat. Success determination criteria do not exist for any other specific wildlife mitigation or reclamation procedures being used by Mine A except for those criteria developed for non-wildlife disciplines.

The determination of successful wetlands restoration will be assisted by an interdisiplinary committee composed of "third-party" professionals. This Wetlands Advisory Committee, still in its formative stages, will be involved in the reclamation process from an advisory standpoint, and will help determine multi-disciplinary monitoring data needs and assist in the development of qualitative and quantitative performance standards. Wildlife monitoring data collected from 1) wetlands prior to mining, 2) wetlands and adjacent areas being mined, and 3) reestablished wetlands, will be reviewed by this committee throughout the monitoring period to determine whether wildlife use of these wetlands has been restored. The committee also will review data from the hydrologic and vegetation disciplines to assess reclamation from these standpoints as well. One of the current activities of this group is the development of criteria or standards on which future judgement on the success of wetland restoration can be based. According to USFWS personnel, these standards will be as flexible as possible to accomodate parameters that are still evolving.

However, it will be the regulatory authority's sole responsibility to make decisions regarding reclamation success and bond release.

3.2.7 Summary of Identified Concerns or Problems

Mine A's major concern with respect to reclamation for wildlife habitat is focused on as-yet-unproven techniques for wetland restoration and the associated performance standards being developed by the Wetlands Advisory Committee. Another issue stems from the conflict between the land uses of agriculture and wildlife habitat. Except where Mine A purchases the land surface, the surface owners usually are farmers or ranchers who logically desire all post-mining land returned to agricultural production. Conflicts arise from this situation because North Dakota's natural wildlife habitat is limited in areal extent and is "shrinking" each year due to water developments, urban expansion, and agricultural expansion. Mine A is addressing this problem by replacing pre-mining wildlife habitat on an acre-for-acre basis following mining.

3.3 Mine B

3.3.1 Description of Appropriate Site Characteristics and Information

Mine B is located in west-central North Dakota and has been in operation since the early 1940s. Coal is mined by dragline and conveyed to a local power generation station. Premining land uses included rangeland, cropland, and hayland, with wildlife habitat as a subordinate use. Mined lands will be reclaimed to these pre-mining uses.

The climate of the area is classified as continental with considerable variation in both diurnal and seasonal temperatures. Average annual precipitation is approximately 16 inches, and the westerly winds average about 10 miles per hour. The primary landform on which the mine is situated is classed as a dissected plateau. Intermittent streams have formed a well-defined dendritic pattern as a result of erosional forces. Soils range from deep, fertile soils in nearly level terrain to shallow soils overlying slopes adjacent to drainages.

Pre-mining vegetation included agricultural communities such as croplands and haylands, as well as native prairie. Woody draws and a few small wetlands are occasionally present and are considered by the NDGFD as critical to the existance of many endemic wildlife populations. Woody draws are present in the intermittent and perennial drainages that flow toward the Missouri River.

3.3.2 Focus of Wildlife Concerns

Land use prior to mining consisted primarily of rangeland and cropland. As such, the endemic wildlife community exhibited a cross-section of agriculturally-adapted and native wildlife species. Both white-tailed and mule deer occurred onsite. White-tailed deer winter along the Missouri River floodplain and move into the Missouri Breaks as spring approaches. Mule deer are associated primarily with the dissected plateau. Pronghorn occasionally are sighted within the mine area. Sharp-tailed grouse are the most numerous native upland gamebird species and several breeding grounds ("leks") exist on or near the permit area. Ring-necked pheasants, normally associated with the alluvial terrace landform, breaks, and agricultural areas, are also a common species. Less numerous upland gamebird species include the gray partridge and turkey. A wide variety of raptors inhabit and nest in and near the permit area. Waterfowl are common visitors to the scattered wetlands within the area. No threatened or endangered species, with the exception of the bald eagle and peregrine falcon, have been observed. The sightings of eagles and a falcon were thought to be of migrating individuals. These species are not believed to be dependent on the permit area for life requirements.

The major wildlife concern on Mine B is the preservation or reestablishment of the "woody draw" vegetation community. Though woody draws comprise a very small area in relation to the acreage to be mined, the value of this habitat is disproportionately greater than its limited acreage would indicate. The tree and shrub species of woody draws offer food, cover, breeding habitat, and vegetative species diversity not found within the other habitats on the mine area. In a region dominated by rangeland and cropland, these draws are essential to the maintenance of the endemic wildlife populations.

Mine B has conducted reclamation research on the reestablishment of woody draws since 1977. Though results are not conclusive, the reestablishment of this habitat type appears feasible given preliminary analyses of research data and intuitive assessments by mine personnel.

From the beginning of woody draw research, the importance of the hydrologic, vegetation, and soils components in the formation of the system have been recognized. Additional information pertinent to woody draw reclamation may be found in companion reports associated with this project.

3.3.3 Methods and Data

Baseline wildlife data collection for this permit began in 1979 and was completed in late 1980. Studies were completed primarily in response to the regulatory authority's requirements. Data were collected for the major species groups known to exist on the proposed permit area (see Table 7). Special emphasis was placed on data collection for big game, raptors, upland gamebirds, and songbirds. Additional studies were completed on songbird occurrence in woody draws to provide information to describe and understand mining impacts on these species. Subsequent to baseline studies, a monitoring program (see Table 7) was conducted for two years by Mine B personnel. The results of this program were included with initial baseline data in the permit application.

The data collected were used primarily to satisfy regulatory authority requirements for wildlife resources information. However, a significant amount of species occurrence, relative abundance, and especially habitat preference data for various species groups were intuitively evaluated to develop wildlife mitigation plans and the post-mining wildlife monitoring plan.

TABLE 7

Wildlife Methods and Data Collected
for Species Groups at Mine B

Species Group Methods	When Used	Data Collected
Big Game		
Aerial Survey	B	Relative Abundance, Concentration Area, Habitat Affinity
Spotlight Survey	B,M	Relative Abundance, Species Occurrence, Population Trends, Habitat Affinity, Concentration Areas
Incidental Sighting	B,M	Relative Abundance, Habitat Affinity
Medium-sized Mammals		
Aerial Survey	B	Species Occurrence, Den Locations
Incidental Sighting	B,M	Species Occurrence, Relative Abundance
Small Mammals		
Trapping	B,M	Species Occurrence, Relative Abundance
Incidental Sighting	M	Species Occurrence
Raptors		
Aerial Survey	B	Nesting Areas, Species Occurrence, Relative Abundance
Ground Survey	B,M	Nesting Areas, Species Occurrence, Reclamation Success (No. of Territories), Distribution
Upland Gamebirds		
Aerial Survey	B	Relative Abundance, Population Estimate, Concentration Area
Crowing Counts	B,M	Species Occurrence, Relative Abundance
Breeding Survey	B,M	Habitat Affinity, Leks, Relative Abundance, Distribution,
Flush Survey	B,M	Reproductive Success
Incidental Sighting	B	Species Occurrence

TABLE 7 Cont.

Species Group Methods	When Used	Data Collected
Waterfowl and Shorebirds		
Breeding Surveys	B	Species Occurrence, Relative Abundance Brood Rearing Success
Songbirds and Others		
Internat. Spot	B,M	Species Occurrence, Relative Abundance, Species Diversity
Quarter Section	B	Species Occurrence, Relative Abundance, Habitat Affinity
Roadside Survey	B	Species Occurrence, Relative Abundance, Habitat Affinity
Winter Survey	B,M	Species Occurrence, Relative Abundance, Habitat Affinity
Incidental Sighting	M	Species Occurrence
Reptiles and Amphibians		
Incidental Sighting	M	Species Occurrence
T, E, & Sensitive		
Incidental Sighting	B,M	Species Occurrence

B = Baseline Studies
M = Monitoring Studies

3.3.4 Impact Analysis and Monitoring

Based on the permit documents, a detailed impact analysis for wildlife resources was not conducted for the entire permit area. The impact analysis in the permit application centered primarily on an intuitive assessment of impacts on woody draw wildlife habitat. This assessment generally considered all species groups dependent at some time on this vegetation community. Mine B personnel have indicated that all woody draw wildlife data gathered for the mine site were used for this intuitive assessment. The impact analysis was based on such factors as seasonal species distribution, adjacent habitat quality, land use of the permit area and the surrounding region, proposed reclamation plans, and past wildlife research.

According to Mine B personnel, the primary objectives of the monitoring plan are to demonstrate how populations have responded to vegetative reclamation and habitat development and to develop information relative to mining impacts on wildlife populations. The wildlife data collected during the baseline studies will serve as a foundation with which monitoring results can be compared. This comparison will allow semi-quantitative assessments of the success of wildlife reclamation based on changes in relative species abundance, species habitat affinity, reproductive success, and population trend data. In addition, Mine B personnel believe that ongoing monitoring efforts may eventually allow statistical and/or other quantitative analyses of songbird population response to woody draw reclamation.

The monitoring program developed for Mine B is fairly extensive, and wildlife will be monitored by species or group and by habitat indicator species (songbirds). Wildlife responses, particularly those of songbirds, to reclaimed woody draws will be emphasized by the monitoring program. In the future, wildlife population changes will be monitored on both disturbed and undisturbed areas for comparison purposes. Breeding non-game bird surveys and winter bird counts will be conducted three years prior to bond release. Sharp-tailed grouse dancing grounds, raptor nests, and raptor territories currently are being monitored annually. Pheasant, mule deer, and white-tailed deer populations also are monitored annually. Small mammal populations will be sampled two consecutive years prior to final bond release to determine species presence, abundance, and diversity.

3.3.5 Mitigation Planning

Wildlife mitigation planning was based primarily on information collected during the vegetation and wildlife baseline inventories. The vegetation components of important onsite wildlife habitat features were determined from the vegetation baseline data. From the wildlife baseline inventory, population estimates, habitat preferences, concentration areas, and species occurrence data were evaluated. Historical wildlife food and cover preference data also were reviewed. From this evaluation, wildlife population habitat needs were assessed and the mitigation plan developed.

Preservation, reestablishment, or enhancement of important premining wildlife habitat features are the focus of the mitigation plan. Woody draws will be avoided during mining or reestablished following mine operations. During reestablishment of woody draws, shrub and tree species important for wildlife food and cover will be planted in configurations beneficial as wildlife habitat. Seed mixtures to be planted incorporate species of known value as wildlife cover and food sources. Two shelterbelts (windbreaks) will be established to provide additional cover and species diversity. Permanent water impoundments and wetlands will be developed, in part, to provide for wildlife watering needs. A 480-acre area established on previously-mined land near the permit area will be managed solely for wildlife.

3.3.6 Success Determination Methods

According to permit documentation and discussion with Mine B personnel, the success of wildlife mitigation techniques will be evaluated using vegetation parameters. The release of bond monies held to ensure success will depend on this evaluation. For woody draw revegetation, the primary wildlife concern, vegetation standards such as woody plant density and diversity and a specific ground cover standard to be achieved following reclamation are central parts of the success standard. Though not a direct wildlife measurement, such standards are important for determining the successful replacement of the floral habitat features upon which wildlife are dependent. The evaluation of success in replacing other land uses also involves measurement of revegetation parameters.

As discussed above, Mine B personnel will monitor major wildlife species groups as a part of post-reclamation activities (see Section 3.3.4) Of particular importance are bird associations in native woodlands because songbird diversity and populations are directly correlated to the quality of woody draw habitat. Mine personnel consider the population trends among these "indicator species" in reclaimed draws to be indicative of reclamation success. Such information will be useful in supporting success evaluations based on vegetation criteria. It must be noted, however, that such monitoring and the resulting data are not a required portion of the bond release process.

Presently, mine personnel believe that insufficient time has passed to comment on the success of mitigation techniques. Draws reclaimed in the past have not matured to a level that would allow such an evaluation. However, mine personnel have noted increasing bird and small mammal use of the "Demonstration Draw" begun in 1977.

3.3.7 Summary of Identified Concerns or Problems

The wildlife concern of greatest importance on Mine B is the reestablishment (along with avoidance in certain areas) of the woody draw habitat. This vegetation community is important, both directly and indirectly, to several groups of wildlife inhabiting the permit area. The bulk of impact assessment and mitigation planning efforts have been directed toward woody draw reestablishment. Preliminary research results indicate that reestablishment is feasible. Wildlife and vegetation baseline data were the primary data used to develop woody draw reclamation plans. However, vegetation monitoring data will be used as the only required criteria for bond release. Wildlife monitoring data will be used only as support information for vegetation monitoring data in determination of reclamation success.

3.4 Mine C

3.4.1 Description of Appropriate Site Characteristics and Information

Mine C is located in southeastern Montana within the northern reaches of the Powder River Basin. Mining occurs as a truck-shovel haulback and dragline operation. Coal is transported offsite by rail. The mine complex has been in operation since 1972.

The climate of the area is described as continental steppe with an average annual precipitation of 11.3 inches. Winds are westerly with an average speed of eight miles per hour. The principal premining land use was grazing by domestic livestock, with some agricultural land and wildlife habitat. Post-mining land use, as determined by the operator, will be a combination of livestock grazing and wildlife habitat.

Topographically, the mine is located on a slightly rolling bench dissected by ephemeral tributaries to the Tongue River System. Soils range from deep alluvial soils to rocky shallow residual soils on steeper uplands. Vegetation communities occurring on the mine include the sagebrush steppe, grassland sagebrush, and mid-short grass prairie. Small areas of ponderosa pine/juniper communities exist onsite and riparian communities can be found in areas adjacent to the mine.

3.4.2 Focus of Wildlife Concerns

Prior to mining, the majority of the area's surface was grazed intensively by domestic livestock. In addition, a wide variety of wildlife species used habitats on and adjacent to the mine. Big game included pronghorn, mule deer, and white-tailed deer. Several species of raptors used habitats on and near the mine. Most notable were golden eagles, which did not nest on the mine site, but were year-long residents of the area. American kestrels were also commonly recorded on the area. Osprey are associated with a nearby reservoir and adjacent riparian habitats. Other common avian species included sage grouse (one strutting ground was located on the mine), great blue heron and double-crested cormorant (residents of the nearby reservoir), and a variety of songbirds. Bald eagles, which occasionally fed and wintered at the nearby reservoir, were the only Federally listed threatened or endangered animal found occasionally in the area.

The entire wildlife community at Mine C was emphasized by the state regulatory authority, and survey efforts by mine personnel addressed all species groups. In addition, Mine C personnel implemented studies beyond those required by the regulatory authority to address areas of impact assessment where their professional biological opinions differed from those of federal agency personnel.

As part of this additional effort, special emphasis was directed toward big game (pronghorn and mule deer) and raptor use of the proposed permit area in a cooperative effort between Mine C personnel and the

USFWS. This study was initiated prior to the promulgation of SMCRA. Another effort involved an investigation of sage grouse habitat preference and fidelity to historic breeding grounds. The path of future mining was expected to remove a known lek or strutting ground (breeding area) and resultant impacts were unknown. A third investigation studied wildlife utilization of riparian habitats along a nearby river and reservoir. A diversity of wildlife species occurred in this area, and the potential effects of a nearby mining operation on these populations were unknown prior to mine development.

3.4.3 Methods and Data

Mine C personnel initiated baseline data collection on unmined areas in 1974, three years prior to SMCRA. These wildlife surveys were preliminary, and in the following year Mine C and the USFWS initiated a cooperative study on the pronghorn and mule deer herds and the raptors found on and near the mine area. Subsequent to these efforts, comprehensive studies addressing all wildlife species were initiated, with many continuing today as monitoring investigations. These studies were performed in direct response to the regulatory authority and state game and fish department's requirements, as well as the mine personnels' desire to understand the effects of their operation on the local wildlife community.

Data were gathered seasonally by habitat type for all species groups known to exist in the mine area. Those special areas of concern identified above were emphasized in the impact assessment. Methods employed extensive direct observational monitoring of radio-collared and marked animals over a period of several years. The methodology and data obtained are summarized in Table 8. All data collected were used to satisfy permitting requirements, and it is anticipated, by mine personnel, that data will be used more completely in the future for an assessment of impacts.

3.4.4 Impact Analysis and Monitoring

As previously indicated, most data have been or will be used for direct and/or comparative impact assessments or for preliminary indications of impact. Direct observational documentation of telemetered sage grouse has shown a shift in fidelity from one breeding area (in the path of mining) to another lek (offsite) created by Mine C personnel. According to permit documentation, additional data over time will be required to provide similar definitive assessments of attempted mitigation with respect to big game. Data for other species groups such as herpetofauna and fish were used for an intuitive assessment of impacts.

Ongoing monitoring (annual or triannual) is collecting data that will be used in future analyses of impacts. In this manner Mine C personnel hope to compare premining data, during mining data, and post-mining reclamation data to determine by semi-quantitative analyses, where possible, if the impacts are due to the mining operation or to natural variation in animal populations or other natural influences such as climate.

In some cases, data already have shown with reasonable certainty the influence the mining operation has had on a specific aspect of the wildlife community. The extensive studies performed for the experimental sage

TABLE 8

Wildlife Methods and Data Collected for Species Groups at Mine C

Species Group Methods	When Used	Data Collected
Big Game		
Aerial Survey	B,M	Relative Abundance, Distribution, Habitat Affinity, Reproductive Success/Location, Concentration Areas, Population Trend
Telemetry	B,M	Home Ranges, Movement Patterns, Distribution, Habitat Affinity
Ground Surveys	B,M	Relative Distribution, Habitat Affinity, Population Index
Fecal Analysis	B,M	Food Preference
Medium-sized Mammals		
Scent Stations	B,M	Species Occurrence, Relative Abundance
Night Spotlighting	B,M	Species Occurrence, Relative Abundance, Habitat Affinity
Small Mammals		
Trapping	B,M	Species Occurrence, Relative Abundance, Species Diversity
Raptors		
Ground Observation	B,M	Nest Sites, Species Occurrence, Reproductive Success
Upland Gamebirds		
Telemetry & Tagging	B	Home and Breeding Ranges, Movement Patterns, Winter Distribution, Habitat Affinity
Aerial Survey	B	Habitat Affinity, Distribution, Relative Abundance
Crowing Counts	B,M	Species Occurrence, Relative Abundance
Breeding Survey	B,M	Leks Locations, Relative Abundance, Population Index

TABLE 8 (Cont.)

Species Group Methods	When Used	Data Collected
Production Survey	B,M	Brood Rearing Habitat, Reproductive Success
Incidental Sighting	B,M	Species Occurrence, Habitat Affinity
Waterfowl and Shorebirds		
General Observation	B	Species Occurrence, Migratory Occurrence, Habitat Utilization
Breeding Surveys	B,M	Species Occurrence, Habitat Utilization, Brood Rearing Habitat
Production Surveys	B,M	Reproductive Success
Songbirds and Others		
Strip Transects	B,M	Species Occurrence, Relative Abundance, Habitat Affinity, Species Diversity
Qualitative Obs.	B	Species Occurrence, Habitat Affinity
Reptiles and Amphibians		
Ground Surveys	B	Species Occurrence, Relative Abundance, Habitat Affinity
Incidental Sighting	B,M	Species Occurrence
Fish		
Literature Review	B	Species Occurrence, Relative Abundance, Habitat Quality
Creel Census	M	Species Occurrence, Relative Abundance
T, E, & Sensitive		
Incidental Sighting	B,M	Species Occurrence

B = Baseline Studies
M = Monitoring Studies

grouse strutting ground relocation appear to indicate successful transfer of fidelity from the old ground to the new ground, thereby eliminating a potentially significant impact to the local sage grouse population. Documented decreases of breeding activity at the old ground correlate strongly with increases in breeding activity at the new ground, relocated offsite. An additional research project started in 1980 by Mine C, with sage grouse leks, attempts to determine whether this shift in fidelity was natural or man-induced. These efforts are continuing, but findings are inclusive at this time.

In other cases, baseline and monitoring data have provided only indications of the impact or lack thereof of mining. Much more time will be necessary before definitive assessments can be performed. For example, both the mine's influence and the effect of certain mitigation measures on the big game population (e.g., browse species in the seed mix) cannot be totally isolated from natural population fluctuations and animal movements. As mining, mitigation, and monitoring progress, more information will be available for analysis over a greater length of time.

In still other cases, baseline and monitoring data presented in the application documents have not shown any definitive indication of impact, or lack thereof, due to mining. According to Mine C personnel, observed natural environmental variation overwhelms the potential effects of mining on some species groups. For example, even the extensive studies (over 30,000 trap nights of effort and statistical analyses of data) performed to obtain small mammal population estimates could not segregate the population changes due to climatic influences from other sources of natural or man-induced variation. As a result, Mine C's monitoring efforts in this area were reduced and only semi-quantitative comparisons are expected in the future.

3.4.5 Mitigation Planning

Wildlife mitigation at Mine C emphasizes four areas: 1) compliance with performance standards (30 CFR 816.97); 2) avoidance of areas of documented importance to wildlife; 3) enhancement of wildlife habitat on reclaimed sites; and 4) enhancement of wildlife habitat in surrounding undisturbed sites. The first involves typical commitments by western mines to comply with the performance standards outlined in the regulations. For example, all power transmission facilities are or will be designed and constructed to prevent electrocution hazards to raptors.

The second area of mitigation involves avoidance of areas of documented importance to wildlife. In the vicinity of Mine C, the major areas of importance are the riparian vegetation community and associated habitats in the vicinity of the nearby river and reservoir. According to permitting documents, mining has not encroached upon these habitats.

The third effort involves a variety of techniques utilized on reclaimed sites for the restoration or enhancement of wildlife habitat. Topographic diversity has been increased through small-scale modifications of regraded spoil and topsoil. These "microsites" - minor depressions, drainages, and hummocks - exhibit a number of different slope/aspect combinations, which in turn encourage a diversity of revegetated plant communities, which are important for reestablishing wildlife diversity. Rock piles constructed on reclaimed areas also contribute to topographic and floral diversity and provide cover for rodents and perching sites for raptors. The revegetation seed mix used at Mine C was based, in part, on the results of pronghorn fecal analyses that identified which plants are preferred forage. In addition, a variety of techniques have been implemented by Mine C in an attempt to increase the success of reestablishment of wildlife-preferred shrubs. For example, shrub test plots were established on a stockpile to determine big game utilization of the forage and the ability of each planted species to propagate naturally.

The last area of mitigation used by Mine C involves a variety of offsite habitat-enhancement techniques. These techniques include: 1) placement of American kestrel nest boxes in appropriate habitats; 2) construction of a freshwater fish-spawning marsh along the periphery of the neighboring reservoir; 3) management of backwater riparian areas to encourage increased waterfowl production; 4) placement of bluebird nest boxes and raptor nesting baskets in appropriate habitats; and 5) vegetation manipulation, including elimination of domestic livestock grazing, for improved mule deer and white-tailed deer foraging habitat.

3.4.6 Success Determination Methods

According to Mine C personnel, no quantitative success determination methods (computer models, statistical analysis, etc.) are being used to evaluate the validity of impact assessment procedures or mitigation efforts. However, general semi-quantitative and qualitative analysis by mine personnel, based on monitoring information, can and will be used when sufficient time has passed, to evaluate success, or lack thereof, of at least some of the mitigation procedures and accuracy of the impact assessments. For example, the use of nest boxes by kestrels for breeding can be considered a success when young birds are observed fledging. Such a qualitative analysis will be possible for many intuitively derived assessments and mitigative procedures.

3.4.7 Summary of Identified Concerns or Problems

Although effects of the mine can be isolated in some instances (e.g., disturbance of sage grouse leks), many other changes to the wildlife community can only be inferred from the quantitative data. Such inferences may take several more years of data, and even then, definitive statements about the causes of impacts or other population changes still will rely on qualitative evaluations of quantitative data. In some instances, massive data collection and analytical efforts may shed more light on the causes of population fluctuations and assist impact assessment, but in others (e.g., small mammal populations at Mine C) the natural fluctuations and behavior of animals cannot be separated from man-induced causes.

3.5 Mine D

3.5.1 Description of Appropriate Site Characteristics and Information

Mine D began operations in 1972 and is located in southern Wyoming. Coal was mined using a dragline and was trucked offsite. Active coal extraction ceased in 1982 and the mine is currently in the reclamation phase of operations. Reclamation activities are targeted for completion in late 1986. Climate of the mine area is characterized as high desert. Precipitation averages from 8 to 12 inches per year. Topography is rolling and is characteristic of this portion of Wyoming. Premining land uses were rangeland, agriculture, wildlife habitat, recreation, and mining. Post-mining land uses will parallel those of pre-mining with an emphasis on wildlife habitat improvement.

In general, the vegetation type is sagebrush steppe. Pre-mining habitats identified on the permit area were bottomland greasewood-sagebrush, upland sagebrush, grassland, rimrock, and disturbed land.

3.5.2 Focus of Wildlife Concerns

Prior to initiation of baseline studies, several important wildlife habitats and features were identified as potentially occurring within the mine permit area. These were: sage grouse leks; critical mule deer and pronghorn wintering areas and summer watering sites; prairie dog towns (potential black-footed ferret habitat); bald eagle and peregrine falcon nest sites; bald eagle winter roost sites; waterfowl nesting and brood rearing habitat; and rimrock areas (raptor nesting habitat).

Baseline data collection for wildlife did not occur prior to the initiation of mining in 1972. Initial baseline studies were implemented in 1978-79 to satisfy the general information requirements of the Wyoming Department of Environmental Quality (DEQ) and determine if any of these important habitats were present. These studies indicated that for the habitats listed above, only rimrock habitat and prairie dog towns were located within the permit area. The initial baseline studies also documented two active golden eagle nests: one in rimrock habitat; the other on a mine highwall. Subsequent monitoring has documented numerous active golden eagle nests on mine highwalls. No Federally listed threatened or endangered species were found to occur on the permit area.

In 1982, the mine ceased coal production and operations shifted to reclamation. As mining activities ceased, there was an associated influx of golden eagles (four pair) which nested on four remaining highwalls. This highwall nesting activity posed a conflict for the mine operator, in that Federal and state laws prohibit leaving a highwall but also prohibit disturbing or destroying golden eagle nests. Much of the mitigation planning and monitoring programs developed by this mine were directed toward solving this dilemma.

3.5.3 Methods and Data

Baseline studies were conducted in 1978-79 in response to state and Federal requirements. Yearly monitoring programs have continued since that time. Baseline studies generally addressed all species groups, but emphasis was placed on determining if habitats listed in Section 3.5.2 were present. The methods used and data collected are presented in Table 9.

In 1982, attempts were initiated to relocate two of the highwall-nesting golden eagle pairs to artificial nesting platforms. In addition, the operator submitted an experimental practice request to the DEQ and OSM to leave a partial highwall where one of the other active nests was located. The fourth highwall eagle nest was believed to be an alternate nest site for the eagle pair using the highwall nest site for which the experimental practice was requested. In 1983, the experimental practice request was approved by the OSM and DEQ. Because of the relocation attempts, monitoring was expanded to evaluate nesting on the artificial platforms. A special monitoring program also was initiated by the operator to evaluate raptor and other wildlife use of the reclaimed 'experimental practice' highwall area. This monitoring was an integral part of the approved experimental practice. Methods used and data collected for this special monitoring program also are listed in Table 9.

3.5.4 Impact Analysis and Monitoring

No analytical methods or models were used to assess impacts resulting from continuation of the mining operation. Intuitive assessments based on

TABLE 9

Wildlife Methods and Data Collected for Species Groups at Mine D

Species Group Methods	When Used	Data Collected
Big Game		
Aerial Survey	B,M	Relative Abundance, Concentration Areas, Habitat Affinity, Seasonal Distribution, Reproductive Success/Location
Ground Survey	B,M	Relative Abundance, Concentration Areas, Reproductive Success/Location, Seasonal Distribution, Habitat Affinity
Incidental Sighting	M	Mortality, Illegal Hunting Activity
Medium-sized Mammals		
Scent Stations	B	Species Occurrence, Relative Abundance of Predators
Ground Surveys	B,M	Species Occurrence, Relative Abundance, Habitat Affinity
Small Mammals		
Trapping	B	Species Occurrence, Relative Abundance, Species Diversity, Habitat Affinity
Aerial Survey	B	Prairie Dog Town Locations
Ground Survey	M	Species Occurrence, Relative Abundance, Prairie Dog Town Mapping, Prairie Dog Population Estimates
Incidental Sighting	B	Species Occurrence, Habitat Affinity
Raptors		
Aerial Survey	B	Nest Sites, Species Occurrence, Relative Abundance
Ground Survey	B,M	Species Occurrence, Nest Sites, Nesting Success, Behavioral Response to Mining
Upland Gamebirds		
Aerial Survey	B,M	Lek Locations and Activity
Vehicle Survey	B,M	Reproductive Success, Brooding Habitat
Waterfowl and Shorebirds		
Breeding Surveys	B	Species Occurrence, Relative Abundance, Brood Rearing Success

TABLE 9 (Cont.)

Species Group Methods	When Used	Data Collected
Incidental Sighting	M	Species Occurrence, Relative Abundance, Habitat Utilization
Songbirds and Others		
Strip Surveys	B	Species Occurrence, Relative Abundance, Seasonal Occurrence
Ground Surveys	M	Species Occurrence, Relative Abundance, Habitat Affinity, Seasonal Occurrence
Reptiles and Amphibians		
Incidental Sighting	B,M	Species Occurrence, Relative Abundance, Habitat Affinity
T, E, & Sensitive		
Prairie Dog Town Searches	B	Species Occurrence, (Black-footed Ferret and Burrowing Owl)
Incidental Sighting	B,M	Species Occurrence (Bald Eagle and Peregrine Falcon)
SPECIAL MONITORING STUDIES FOR EXPERIMENTAL HIGHWALL AREA AND CONTROL AREA (Reclaimed to AOC)		
Raptors		
Ground Surveys	M	Species Occurrence, Relative Abundance, Nest Sites and Status, Nest Production, Perch and Roost Sites
Rabbits and Hares		
Ground Transects	M	Species Occurrence, Relative Abundance Indices
Small Mammals		
Live Trapping	M	Species Occurrence, Relative Abundance, Species Diversity
Songbirds		
Ground Surveys	M	Species Occurrence, Relative Abundance, Species Diversity

B = Baseline Studies
M = Monitoring Studies

professional judgement, baseline data, and the mine plan were used for an initial determination of the expected severity of impacts to wildlife species groups. Baseline studies showed that no sage grouse leks, critical pronghorn and mule deer wintering areas and watering sites, threatened or endangered species, or important waterfowl breeding habitats occurred on the mine area. Prairie dog towns were located, but they occurred outside any mine areas. Because these important habitats did not occur in any areas to be affected by mining, impact assessment was based primarily on the total extent of habitat loss and the potential for disturbance to raptor rimrock and highwall nesting habitat.

Loss of habitat was expected to destroy less mobile wildlife species (small mammmals, herptofauna, etc.) and displace more mobile wildlife species (birds, coyotes, pronghorn, mule deer, etc.). The severity of these impacts to permit-area wildlife populations was unknown but expected to be only temporary because reclamation plans were to be implemented, as soon as possible, following mining. The reclamation goals are to replace habitats that existed prior to mining. Early in the planning process, mining was predicted to remove one small rimrock area, which contained an inactive golden eagle nest, and reclamation would remove the highwall eagle nest sites. However, mining operations ceased prior to reaching the rimrock area and this nest site remained intact. The effect of lost golden eagle nest sites on the eagle population in the area were not known, but suitable nest sites generally are considered to be a limiting factor on eagle populations in this region of Wyoming.

The monitoring program was implemented to detect general changes in wildlife species occurrence and population trends in response to mining and reclaimed areas. Special monitoring of raptor nesting activity also was undertaken to assess the effect of nearby mining activities on raptor behavior and nest success. In general, wildlife species, distribution, and population trends recorded by monitoring of undisturbed habitats adjacent to mining activity were comparable to those recorded by the baseline studies. Pronghorn numbers recorded for the study area remained highly variable depending on season of observaton. Very few pronghorn were recorded as road-kills on the mine haul roads. Monitoring of raptor nesting activity has documented an increase in nesting pairs since 1979. In 1982, prior to initiation of nest relocation and highwall reclamation efforts, a total of eight nests were located. Five of these, four golden eagle (3 active, 1 inactive) and one active red-tailed hawk nest were located on highwalls. All four active nests successfully fledged young. Nearby mining and reclamation activities apparently had no detrimental effect on nest success.

3.5.5 Mitigation Planning

Mitigation measures implemented at Mine D can be classified into two general categories, operational and habitat replacement/enhancement. Operational measures consisted of 1) no direct disturbance of raptor nest sites during the breeding season to ensure nest success; 2) enforcement of posted haul and access road speed limits to reduce the potential for wildlife-vehicle collisions, especially for big game; 3) posting of Wyoming Game and Fish Department (WGFD) regulations in prominent places to inform employees of regulations and reduce the potential for poaching and harassment of wildlife; and 4) reporting to the WGFD any observations of poaching activities to reduce the potential for illegal harvest. These measures were chosen on the basis of their documented effectiveness in limiting specific impacts to wildlife.

Habitat replacement/enhancement measures were chosen based on a knowledge of pre-mining habitats and general habitat requirements of resident wildlife species. Specific revegetation considerations included plantings of shrub patches (by tubelings and direct transplant) for establishment of additional food and cover for wildlife as well as development of seeding mixes that contained native species known to provide forage to wildlife. Additional plantings of native shrub seeds were made in select areas, such as drainages and around rock piles, where additional moisture accumulations would increase chances for seedling survival. Shrub species were selected, in part, for their proven value as cover and forage for wildlife.

Other habitat enhancement measures used were placement of rock piles or rubble and large boulders in appropriate areas. Rock piles were established to mitigate the loss of some of the topographic diversity previously provided by small draws and gulches, and to provide cover for a variety of small mammals, rabbits, and hares. They also serve to collect additional moisture (snow) on their leeward sides, increasing chances for shrub establishment and floral diversity. Large boulders were placed or stacked in such a fashion as to provide raptor roosting and nesting sites.

Special procedures implemented to mitigate disturbance or loss of golden eagle and other raptor highwall nest sites included attempts to relocate active highwall nests and the experimental practice of leaving one partial highwall intact. A cooperative effort with the mine operator, USFWS, WDGF, and DEQ was inititated to formulate the best techniques for implementing these procedures. Following consultation, it was decided that the best approach would be to leave one highwall and try to relocate the other two active eagle highwall nests. Choice of highwall was based on the stability of the wall, the quality of nest sites provided by the wall, and the appearance and configuration of the wall in relation to surrounding terrain. Shrub seedings and direct shrub and tree transplants, along with rock pile placements, were made along the base of the wall to provide additional forage and cover for small mammals and rabbits. Nest relocations were attempted by removing fledglings from the active highwall nests and placing them on nearby artificial nesting platforms in an effort to lure the adults to these new nest sites. As additional active eagle nests were established on highwalls in subsequent years, nest relocations have been attempted by moving young to nearby natural rimrock areas or to artificially-established boulder nest sites.

One additional mitigation measure that has been employed is the enhancement of existing natural nest sites in natural rimrock areas. Mine personnel have found that in many cases where a nest has been used year after year, the nest becomes so built up that it renders a nest site unusable. Mine personnel hypothesize that this trend may be partially responsible for the observed shift of golden eagles from natural nest sites to highwall nest sites. In an effort to make filled natural nest sites usable again, mine personnel have been removing some of the layers of the nest to allow access to the nest by adult birds.

3.5.6 Success Determination Methods

No analytical procedures other than those used to employed for revegetation success evaluation are being used to test the success of implemented mitigation measures. However, general monitoring procedures and direct observation of species use of reclaimed areas and habitat enhancement features have provided practical qualitative means of assessing the general success of reclamation and mitigation measures.

General use of reclaimed and adjacent areas by resident wildlife has been documented by monitoring. A significant proportion of the wildlife observations have been made in reclaimed areas, although use of reclaimed areas is less than in adjacent undisturbed habitats. It is expected by mine personnel that as vegetation on reclaimed areas matures and becomes more diverse, wildlife use of these areas also will increase. Considerable small mammal and rabbit use of rock piles also has been documented. Great horned owls have nested on artificial boulder nest sites, and one golden eagle nest was relocated to a boulder nest site where young were fledged successfully. Monitoring of other relocated nest sites has shown that the young were fledged successfully and the adults returned to use these nest sites in subsequent years. Monitoring of enhanced natural nest sites has documented successful use of some of these nests by raptors, although, golden eagles have not renested at these sites according to USFWS personnel. Special monitoring of the experimental highwall has documented nesting by American kestrel. No renesting by golden eagles on the experimental highwall has occurred since reclamation was completed according to USFWS personnel. Small mammals and rabbits are using habitats associated with the highwall and many of the shrub and tree transplants have been successful. Insufficient time has passed, however, to make any valid analytical comparisons between songbird and small mammal data collected for the highwall and control area.

3.5.7 Summary of Identified Concerns or Problems

Mine D's principal concerns are the reestablishment of self-sustaining premine habitats, the establishment of successful highwall habitat, and continuation of successful nesting by breeding raptor species, especially golden eagles. A conflict arose when golden eagles began nesting on remaining highwalls, in that Federal and state laws required the removal of highwalls and also prohibited the disturbance or destruction of eagle nest sites. The situation was resolved by approval of an experimental practice to leave a portion of one highwall and by successful relocation of nests from highwalls that eventually were removed. Monitoring of the experimental highwall and reclaimed habitats has documented some wildlife use of these habitats but much more time will be required to evaluate the total extent of successful reclamation.

3.6 Mine E

3.6.1 Description of Appropriate Site Characteristics and Information

Mine E is located in northwestern Colorado and has been in operation since 1962. Coal is mined primarily by draglines with assistance from other methods as necessary. Coal is then transported offsite by rail.

Climate of the area is classified as highland continental with temperatures subject to wide diurnal and seasonal variation. Average annual precipitation is 16 inches. The topography generally is classed as foothills. Soils are moderately deep and fertile. Both pre- and post-mining land uses are livestock grazing and wildlife habitat. Four major pre-mining vegetation types occur on the permit area: aspen, mountain shrub, sagebrush, and meadow.

3.6.2 Focus of Wildlife Concerns

Elk and mule deer are common big game residents within the permit area. Elk calving grounds, in particular, are a significant issue at this mine. A variety of raptors, including golden eagles, are also common to the site. Sharp-tailed grouse and sage grouse occur within the region but are not present in significant numbers on the permit area. No Federally listed threatened or endangered species are known to exist at the site.

Initially, Mine E was a proposed extension of an existing surface mine. Wildlife information from previous studies conducted in the area and from the Colorado Division of Wildlife (CDOW) provided input for identifying potential areas of wildlife concern related to development of Mine E. Primary concerns were the location of an elk calving ground in the path of proposed mining, a sage grouse strutting ground adjacent to the proposed mine, and golden eagles nesting on sandstone outcrops near the proposed mine. Another less significant concern was the potential effect of mining on water quality in nearby streams and on associated beaver populations in these drainages.

3.6.3 Methods and Data

The operator conducted initial baseline data collection in 1979. These studies also incorporated the results of other preliminary studies conducted in 1975. Baseline studies addressed all species groups, as requested by the regulatory authority, but emphasized locating raptor nests within one mile of the mine plan area, monitoring sage grouse strutting ground activity, and confirming the presence of elk calving habitat. These studies could not document the presence of the historical sage grouse strutting ground but did confirm the presence of elk calving habitat and characterized portions of this habitat.

Based on the elk calving habitat information and on calving ground information available from the CDOW, the BLM invoked Unsuitability Criteria No. 15 and excluded the calving habitat and an associated buffer zone from mining. Additional baseline studies conducted by the operator demonstrated that elk calving habitat was much more extensive than originally thought and showed that major portions of the habitat occurred in adjacent areas off the proposed mine site. As a result of these findings, the regulatory authority agreed to allow mining through the elk calving habitat in the mine plan area, but several special study conditions were included in the permit by the Colorado regulatory authority. These conditions are paraphrased below:

> Using statistically valid sampling techniques, compare the floral characteristics of the mine plan area calving habitat with those of offsite calving habitat occurring on a different soils complex.
>
> Conduct more intensive studies to delineate and describe the physical and floral features the of mine plan area and adjacent elk calving habitat. Based on this information, submit a detailed description of methodologies and criteria to be used in manipulating adjacent habitat to create new calving areas.
>
> Submit a plan showing how and where elk watering areas will be established in relation to elk calving habitat.
>
> Conduct elk monitoring studies to study the effects of coal mining on elk behavior; specifically in relation to removal of portions of elk calving habitat.
>
> Conduct additional surveys to determine if the historical sage grouse strutting ground is still present.
>
> (From: permit correspondence in the regulatory authority's files)

In response to these conditions, the operator conducted additional studies to characterize onsite and off-site calving habitat and determined the need for additional calving areas. These studies showed that adjacent calving habitat was yet more extensive than shown in the previous studies and elk already were using off-site areas for calving activities. In addition, hydrological analyses and surface water inventories showed that ample watering areas (which are important for elk) existed off-site near calving habitat, and that this surface water would not be disrupted by mining.

The CDOW made an evaluation of the historical sage grouse strutting ground and determined that it was a small sharp-tailed grouse dancing ground, and little sage grouse habitat existed in the permit area. Based on the operator and CDOW studies and operator consultation with the regulatory agency and the CDOW, the conditions to monitor the historic sage grouse strutting ground and establish elk calving habitat and watering areas were eliminated. An intensive trapping, tagging, radio-collaring, and monitoring program then was devised and implemented by the operator to study elk response to mining of a portion of elk calving habitat.

Other monitoring programs committed to by the operator included: 1) supplemental seasonal aerial surveys for elk and mule deer; 2) continuation of aquatic biology sampling for fish and invertebrates; 3) qualitative monitoring of beaver activity; 4) monitoring of golden eagle nesting success and behavior within one mile of mining activities; and 5) monitoring of sharp-tailed grouse and sage grouse lek activity near the mine and in surrounding areas. Monitoring of lek activity in surrounding, non-affected areas was undertaken due to the potential for future mine development in these areas.

A summary of all baseline and monitoring studies implemented and data collected is provided in Table 10.

TABLE 10

Wildlife Methods and Data Collected for Species Groups at Mine E

Species Group Methods	When Used	Data Collected
Big Game		
Aerial Survey	B,M	Relative Abundance, Concentration Areas, Habitat Affinity, Seasonal Distribution, Migration Routes
Telemetry and Tagging Studies	M	Elk Calving Home Range, Movement Patterns, Habitat Affinity, Reproductive Success, Mortality, Fidelity to Seasonal Ranges
Ground Survey	B	Characterization of Elk Calving Area
Vegetation/Soils	B	Physical and Floral Aspects of Calving Area
Incidental Sightings	B,M	Relative Abundance, Distribution, Habitat Affinity
Medium-sized Mammals		
Scent Stations	B	Species Occurrence, Relative Abundance of Predators
Ground Surveys	M	Species Occurrence, Relative Abundance (Beaver)
Incidental Sightings	B	Species Occurrence, Relative Abundance, Habitat Affinity
Small Mammals		
Trapping	B,M	Species Occurrence, Relative Abundance, Habitat Affinity
Incidental Sightings	B	Species Occurrence, Relative Abundance, Habitat Affinity
Raptors		
Ground Survey	B,M	Species Occurrence, Nest Sites, Nesting Success, Behavioral Response to Mining
Incidental Sightings	B	Species Occurrence, Relative Abundance, Distribution

TABLE 10 (Cont.)

Species Group Methods	When Used	Data Collected
Upland Gamebirds		
Aerial Survey	B	Lek Locations and Activity
Ground Survey	B	Lek Activity
Incidental Sightings	B	Species Occurrence, Relative Abundance, Habitat Affinity
Waterfowl and Shorebirds		
Surface Water Survey	B	Species Occurrence, Relative Abundance, Habitat Affinity
Songbirds and Others		
Strip Surveys	B	Species Occurrence, Relative Abundance, Species Diversity, Density Indices, Habitat Affinity
Incidental Sightings	B	Species Occurrence, Relative Abundance, Habitat Affinity
Reptiles and Amphibians		
Incidental Sighting	B	Species Occurrence, Relative Abundance, Habitat Affinity
Aquatic Invertebrates		
Grap and Dredge	B,M	Species Occurrence, Relative Abundance, Density, Species Diversity, Habitat Quality
Fish		
Electro-shock & Dip Netting	B,M	Species Occurrence, Relative Abundance, Habitat Quality
T, E, & Sensitive		
Incidental Sighting	M	Species Occurrence

B = Baseline Studies
M = Monitoring Studies

3.6.4 Impact Analysis and Monitoring

Baseline data used for impact assessment generally were restricted to direct observational documentation of species and habitat occurrence within the mine plan area. This information was used, in conjunction with information on the mine and reclamation plan, to make professional intuitive judgements regarding the overall severity of wildlife impacts relating to habitat removal. Baseline studies indicated that raptor cliff nesting habitat, a sharp-tailed grouse lek, beaver habitat, and adjacent surface water would not be affected directly by mining activities. Based on this information, it was decided that most impacts due to direct habitat loss would be temporary and that reclaiming the area to its original habitats and topographic configuration eventually would mitigate these impacts. For other more specific impact concerns, such as disturbance of elk calving habitat and secondary impacts to sharp-tailed grouse, beaver, aquatic habitat, and golden eagle nesting, the operator implemented monitoring programs designed to assess these potential impacts.

Monitoring of sharp-tailed grouse breeding activity on the one dancing ground near the mine documented a decline and then cessation of breeding activity at that lek. Because the lek was more than a quarter mile from the permit area and similar declines in sharp-tailed grouse activity were noted in other non-affected areas, it was assumed that this decline was due to factors other than mining.

Monitoring of beaver activity and aquatic fauna did not document any perceptible trends that could be attributed to mining. Trends in aquatic invertebrate and fish populations appeared to be correlated to inherent seasonal stream variability rather than mining. In 1982, the operator submitted a request, with the concurrence of the CDOW, to the Colorado Mined Land Reclamation Division (CMLRD) to eliminate the aquatic monitoring program. The request was approved by the CMLRD. (Correspondence in CMLRD files and permit application information did not indicate how the aquatic data was analyzed in making this determination.)

After the initial four years of extensive monitoring of mine-area elk herds by radio-telemetry, several significant findings were demonstrated. Aside from temporary losses of aspen habitat, no discernible negative impacts to mine-area elk populations have been determined. No significant differences in reproduction, calving home range size, fidelity to calving home ranges, and habitat utilization have been identified between mine-area elk and control-area elk located in areas undisturbed by mining. There also is no indication that elk have abandoned mine areas; elk use of habitats and calving home ranges occurred within a quarter mile of active mining. Reclaimed areas also have been used by elk, especially in the fall when older revegetation received intensive elk grazing pressure. Mine personnel believe that most of these findings could not have been documented conclusively without the use of extensive radio telemetry monitoring studies.

Direct observational monitoring of golden eagle nest sites and nest success within one mile of mining activities has not identified any negative impacts. Nest sites have continued to be used and birds have fledged young successfully over the last few years. In addition, more intensive observational monitoring of nesting adults during disturbance events such as blasting did not document any perceived changes in adult behavior.

3.6.5 Mitigation Planning

Monitoring did not document any significant negative impacts related to many of the original concerns (listed in Section 3.6.2), and no special mitigation measures were developed to address these concerns. The special elk monitoring program was a permit condition of the Colorado Mined Land Reclamation Division because impacts were uncertain and much research was needed. The results of the special elk studies also will be applicable for use by the CMLRD and CDOW in assessing impacts and formulating mitigation for future mines in similar situations.

Mitigation measures implemented by Mine E were primarily operational or directed at avoidance or habitat replacement/enhancement. They include the typical compliance efforts as required by federal performance standards (30 CFR 816.97). Additional or related mitigation efforts include: 1) limiting operational off-road vehicle use to prevent additional habitat disturbance and harassment of wildlife; 2) prohibiting firearms in the mine area to reduce the potential for poaching; and 3) blasting only during the daylight hours to reduce disturbance during periods when many species of wildlife are most active. These operational measures were chosen on the basis of their documented effectiveness in limiting specific impacts to wildlife.

Avoidance mitigation measures consisted of maintaining a vegetation buffer zone around the entire periphery of the proposed mine area and withholding all operational developments at least a quarter mile back from the sharp-tailed grouse dancing ground. The vegetation buffer zone was left intact to provide food and cover for wildlife, to control noise and dust emissions, and to provide a movement corridor for wildife.

Habitat reclamation/enhancement measures consisted primarily of returning topography and vegetation to premine conditions. The selection of habitat reclamation/enhancement measures was based on a knowledge of premining habitats, topography, and general habitat requirements of resident wildlife species. Specific revegetation measures used to reestablish wildlife habitat included direct transplanting of "islands" of trees and shrubs for more rapid establishment of food and cover for wildlife. This method was used in conjunction with planting aspen clones and seeding shrubs, forbs, and grasses to create a vegetation matrix high with species diversity and spatial heterogeneity. The purpose of these plantings was to speed up successional patterns and to promote reinvasion of naturally occurring vegetation species and to create a diversity of forage and cover known to be beneficial to wildlife. Reclamation also will stress returning mined areas to their approximate original contour and re-establishing drainages. One final habitat enhancement measure implemented was the placement of rock and brush piles to create microclimatic features and provide cover for small mammals. Rock piles also were established to provide perch sites for raptors.

3.6.6 Success Determination Methods

Aside from the monitoring programs discussed previously (Section 3.6.4), no success determination methods specifically addressing wildlife are being utilized. Other than the usual quantitative procedures to test for revegetation success, qualitative observations of wildlife utilization of reclaimed areas have been used for general intuitive assessments of the success of reclamation for wildlife. A considerable amount of research is being conducted by the operator with regard to revegetating shrub and aspen stands on reclaimed areas (see vegetation companion report - Section 3.2).

3.6.7 Summary of Identified Concerns or Problems

The principal wildlife concerns related to the development of Mine E were loss of elk calving habitat, disturbance of golden eagle nest sites, and disturbance of a sharp-tailed grouse dancing ground. Monitoring of the sharp-tailed grouse lek and golden eagle nesting activity in proximity to the mine operation showed no perceptible impact due to mining. Prior to mining, it was not known what effect disturbance and removal of elk calving habitat would have on the local elk population. Because of this, the BLM initially stipulated that elk calving habitat be excluded from mining. Additional studies by the operator showed that calving habitat was more extensive than originally thought and that significant portions occurred outside the mine area boundaries. As a result, the operator was permitted to mine through a portion of the calving area but was required by a permit condition to conduct special monitoring studies to address the question of impacts to the local elk population. Data from four years of extensive radio-telemetry monitoring of the elk herd documented that, at least for the period studied, mining a portion of calving habitat had no significant impact on the mine-area elk population.

3.7 Mine F

3.7.1 Description of Appropriate Site Characteristics and Information

Mine F is located in northwest Colorado. Coal is removed by dragline operation and trucked to a nearby power generation station. Premining land uses included rangeland with a coincidental subordinate use of wildlife habitat, along with a small amount of agricultural area (dryland crop and hayland). Post-mining land uses are designated as croplands on lower areas of less than 12 percent slope, grazing lands on steeper slopes up to a particular elevational contour, and wildlife habitat above the grazing lands.

The climate is characterized as highland continental with 13.5 inches of annual precipitation, large fluctuations in diurnal temperatures, and westerly winds. The topography is moderately steep to steep rolling foothills. Ephemeral drainages add to the broken nature of the topography.

In general, the soils are relatively deep and well-drained. Vegetation varies widely due to climatic and edaphic influences.

Predominant vegetative communities on the mine area include mountain shrub, sagebrush/grassland, and some cropland. These communities have been modified to varying degrees by domestic animals through intensive grazing and by man through surface manipulations such as plowing, burning, and chaining.

3.7.2 Focus of Wildlife Concerns

Prior to mining, elk and mule deer were seasonal residents of the permit area as were a variety of other species including blue grouse, sage grouse, and sharp-tailed grouse. Raptors, such as golden eagles, also were known to nest in the area. One BLM lease stipulation required cessation of activity in particular portions of the lease between March 1 and July 31 to provide a temporal buffer zone around nesting prairie falcons.

Since mining began it has been noted that big game use of the mine and adjacent areas has increased significantly. Mine personnel indicated that winter use of the mine area by elk has tripled, and a small herd of pronghorn has taken up residence and is increasing. This phenomenon is largely unexplained but may be due at least in part to the "refuge effect" common to mining operations.

Because of the economic importance of big game to northwest Colorado (much revenue is generated by hunting in the state), particular attention often is given to these animals by the state regulatory authority. In addition, the USFWS consistently places emphasis on protection of raptor species in areas of potential disturbance.

3.7.3 Methods and Data

The majority of wildlife baseline data collection occurred prior to the passage of SMCRA and involved fairly comprehensive inventories of most species groups of animals. Methodology and data obtained are summarized in Table 11. Following these efforts, which were aimed at satisfying then existing permitting requirements, mine personnel decided to monitor, for their own benefit and possible future need (e.g., request for data by the regulatory authorities), certain wildlife populations and parameters. This monitoring consists primarily of seasonal aerial and ground surveys to determine big game population trends and distribution and raptor nesting use on, and adjacent to, the mine area.

3.7.4 Impact Analysis and Monitoring

Data obtained by wildlife inventories have not been used in analytical impact assessments. Data were used to make intuitive judgements and assessments of potential mining impacts and needs for mitigation. For example, baseline big game inventories and ongoing monitoring have shown that animals were not present during the severest parts of a severe winter indicating that the mine area does not contain critical winter range. Baseline distribution information also has been used to identify the most appropriate areas to reclaim as big game habitat.

Other qualitative information used by the mine's biologists for intuitive impact assessments included: expected versus observed animal reactions to similar mining operations; the direction and intensity of

TABLE 11
Wildlife Methods and Data Collected for Species Groups at Mine F

Species Group Methods	When Used	Data Collected
Big Game		
Aerial Survey	B,M	Relative Abundance, Distribution, Habitat Affinity, Reproductive Success, Concentration Areas
Pellet Counts	B,M	Habitat Affinity, Population Index
Ground Transects	B	Habitat Utilization
Medium-sized Mammals		
Track Counts	B	Species Occurrence
Small Mammals		
Trapping	B	Species Occurrence, Relative Abundance
Incidental Sightings	B	Species Occurrence (Bats)
Raptors		
Aerial Survey	B,M	Species Occurrence, Nesting
Ground Survey	B,M	Species Occurrence, Nesting
Avifauna		
Roadside Transects	B	Species Occurrence, Relative Abundance
Reptiles and Amphibians		
Incidental Sighting	B	Species Occurrence
Aquatic Invertebrates		
Seining & Dipping	B	Species Occurrence

B = Baseline Studies
M = Monitoring Studies

mining; quality of adjacent habitats; presence or absence of suitable habitat for a given species; distance from the operation; and the inherent ability of animals to adapt. In some instances, certain baseline data (small mammal, passerine, herpetofauna, macroinvertebrates) have not been considered as strongly in the intuitive evaluation of impacts or mitigation needs as have game animal and sensitive species data. This is reflective of the CDOW's concern over game animals, sensitive species, and other legally protected wildlife.

In other instances, especially where there was a possible future need for big game and raptor data to support impact assessments, mine officials decided to institute a monitoring program. Based on professional judgement, Mine F officials decided that suitable monitoring data could be obtained by performing, twice-per-month, November through May, aerial surveys to determine big game distribution and numbers with respect to snow depth. (Snow accumulations beyond specific depths have been shown by numerous studies to limit big game use of an area.) Also, aerial surveys are performed every third year in adjacent habitats to assess calving activity by elk.

Another monitoring program performed at the mine involves a raptor nesting survey each spring. This program monitors nesting success of five nesting pairs of golden eagles in the area. Additional monitoring, to be instituted in 1986, will involve pellet-group surveys on reclaimed areas to assess relative big game use of these areas. These data then will be compared to ongoing pellet group monitoring occurring in off-site areas that have been enhanced, through vegetation plantings or manipulations, for big game. Pellet-group surveys provide information on the occurrence and density of big game fecal material for use as an indirect measurement of big game use of an area or particular habitat. The resulting numerical data will be compared in an unknown manner (the permit application did not specify any analytical or qualitative methods) to demonstrate the value of reclaimed areas for big game.

General semi-quantitative analyses by Mine F personnel, based on monitoring information, suggest that negative impacts to big game are not occurring, and that impacts may in fact be positive ("refuge effect"). Monitoring of raptors nesting in the vicinity of the mining operation has indicated a lack of adverse effects, as the nesting birds seem to have adapted to the activity of the mine, according to mine personnel.

3.7.5 Mitigation Planning

As discussed in the introduction to Chapter 3.0, Mine F is in compliance with the wildlife performance standards (30 CFR 816.97). Additional mitigative measures were chosen by the operator based on a knowledge of baseline data, the mining operation, and professional judgement. These measures include: 1) offsite enhancement of big game range by crushing overmature stands of vegetation to create areas with increased and better quality forage production for wildlife; 2) direct transplanting of endemic shrub clumps to provide sources of browse, thermal cover, and escape cover for big game species; 3) direct hauling of topsoil to obtain greater diversity of vegetation on reclaimed areas; 4) planting of seed mixes that include plant species specifically intended for wildlife forage or cover; 5) occasional construction of rock piles for small mammal habitat and perch sites for raptors; 6) establishment of nesting boxes for kestrels; 7) establishment of windbreaks, that include plantings of an introduced tree species beneficial to wildlife, to reduce soil erosion; and 8) maintenance of "lay down" fences that are raised or lowered depending on season and big game migratory movements.

3.7.6 Success Determination Methods

As with impact assessment, no quantitative criteria exist for evaluating the success of mitigation techniques. Qualitative observations by mine personnel of animal use of reclaimed areas, sedimentation ponds, and nesting areas indicate at least some success of most mitigation techniques. For example, mine personnel have observed transplanted shrub plots being used by mule deer for thermal and escape cover while feeding on the newly revegetated areas. Also, according to mine personnel, the off-site shrub-crushed areas seem to be attracting a few more big game animals, but more time is needed to confirm this. In addition, raptors have been seen perching on established rockpiles. Insufficient time has passed for mine personnel to make an intuitive evaluation of the success of other mitigation techniques.

3.7.7 Summary of Identified Concerns or Problems

According to Mine F personnel, the mine has no major wildlife concerns. However, monitoring is being conducted to assess big game use of the mine area and raptor nesting success in adjacent areas.

Of particular interest is Mine F's approach to reclamation with respect to post-mining land uses. According to mine personnel, the post-mining land use governs how and where reclamation practices are to be implemented. This approach involved reestablishing pre-mining land uses on the post-mining topography. Land uses were established according to slope and elevation such that the best management practices could be applied for each land use. No attempt was made to reestablish uses in the areal configuration in which they existed prior to disturbance. This differs from more typical approaches where land unit for land unit is returned to its pre-mining use. This unique approach matches landform to suitable land use designations and reduces the temptation for subtle post-mining land use alterations from wildlife habitat. In other words, reclamation of disturbed land to specific land use categories is based on what the most appropriate use of a particular landform would be. For example, level to gently-sloping areas are being reclaimed as cropland, while steeper or more broken terrain is being reclaimed as wildlife habitat.

With respect to impact assessment and mitigation success determinations at Mine F, insufficient time has passed to evaluate the extent of negative or positive impacts or the success of mitigation techniques.

3.8 Mine G

3.8.1 Description of Appropriate Site Characteristics and Information

Mine G is located in northeastern New Mexico and began operations in 1962. Coal is produced by dragline, truck-shovel, and underground operations and is transported off-site by rail. The climate of the area is arid with ~~an~~ average annual precipitation of 10.6 inches. Winds are westerly with an average speed of approximately 7 mph. Terrain is hilly and broken by southeasterly-flowing drainages. The basin in which this mine is located is typified by several flat-top ridges separated by narrow water courses. Relief varies between 500 and 2000 feet. In general, the soils are moderately shallow deep and well drained.

The primary pre-mining land uses were livestock grazing and wildlife habitat. The primary post-mining land use will be wildlife habitat. Vegetation types fall into 19 classes which in turn, comprise five floral communities: upland meadows, grasslands, meadow bottomland, mixed conifer, and ponderosa pine/oakbrush. These communities include a wide variety of shrub and conifer species.

3.8.2 Focus of Wildlife Concerns

Prior to mining, affected lands were managed specifically for big game (elk and mule deer). Other big game animals included black bear and mountain lion. The turkey was the only upland game bird known from the site. Bald eagles have been observed passing through the area as migrants, but no other federally listed threatened or endangered or state sensitive species are known to inhabit this area of New Mexico. Aquatic habitat in the vicinity of the mine area is limited and does not qualify as a "high quality cold water fishery" (NMDGF classification). However, some streams in the region are designated as a "cold water fishery" according to New Mexico Water Quality Standards.

According to the state regulatory authority personnel Mine G is unique among active New Mexico mines as it is the only mine in the state with wildlife habitat as the principal post-mining land use. The post-mining use was specified primarily by the mine's surface owner, an adjacent ranch operator who maintains a strong economic interest in the health of resident big game herds. Because of this interest, the mine entered into a cooperative agreement with the surface owner several years ago for extensive monitoring of the big game herds (primarily elk but also mule deer) in conjunction with the surface owner's wildlife monitoring efforts. By monitoring, it was hoped that the influence or lack thereof of the mine on big game populations could be determined and appropriate mitigation implemented. In addition, Mine G personnel decided that other non-big game wildlife data should be collected in case it was needed for future comparisons, public relations, or possible future regulatory requirements, and a program was instituted.

Initially, the state regulatory authority found Mine G's wildlife data gathering effort to be satisfactory. However, the New Mexico Department of Game and Fish later required Mine G to place more emphasis on non-game animals and fish. In response to this requirement, additional studies have been undertaken.

This additional wildlife data is being collected to provide the game and fish agency with an overall picture of the wildlife ecology of the mine area. Mine personnel have indicated that they were not directed to use this data for specific impact assessment or mitigation planning purposes, but that it might be needed for future comparisons between premining and reclaimed lands' wildlife populations to determine reclamation success.

3.8.3 Methods and Data

Baseline data collection for wildlife did not occur prior to the initiation of mining in the early 1960s. However, monitoring of mule deer and elk as well as other general wildlife monitoring began in 1978. More comprehensive wildlife inventories were initiated in 1980. In many instances, these data were gathered from adjacent lands where future mining may occur and therefore could be treated as baseline for the existing operation. Beginning in 1982, as a result of NMDGF requests, the overall monitoring and data gathering efforts were changed significantly so that the emphasis of monitoring for non-game animals would parallel that for game animals. The methodology and data obtained are summarized in Table 12.

TABLE 12

Wildlife Methods and Data Collected for Species Groups at Mine G

Species Group Methods	When Used	Data Collected
Big Game		
Telemetry	B,M	Home Ranges, Movement Patterns, Distribution, Habitat Affinity
Aerial Survey	B,M	Relative Abundance, Distribution, Habitat Affinity, Reproductive Success, Concentration Areas
Pellet Counts	B,M	Habitat Affinity, Population Index
Hunt Monitoring	M	Age, Hunter Satisfaction
Medium-sized Mammals		
Trapping	B	Species Occurrence, Relative Abundance
Night Spotlight	B	Species Occurrence, Relative Abundance, Habitat Affinity
Cache Survey	B	Occurrence of Beaver, Relative Abundance, Distribution, Habitat Quality
Small Mammals		
Trapping	B	Species Occurrence, Relative Abundance
Incidental Sighting	B	Species Occurrence
Raptors		
Incidental Sighting	B	Species Occurrence, Nesting Areas
Upland Gamebirds		
Incidental Sighting	B	Species Occurrence
Songbirds and Others		
Strip Transects	B	Species Occurrence, Relative Abundance, Habitat Affinity, Species Diversity
Reptiles and Amphibians		
Incidental Sighting	B	Species Occurrence
Fish		
Electro-shocking	B	Species Occurrence, Relative Abundance, Habitat Quality

TABLE 12 (Cont.)

Species Group Methods	When Used	Data Collected
Aquatic Invertebrates		
Bottom Grab Samples	B	Species Occurrence
T, E, & Sensitive		
Incidental Sighting	B,M	Species Occurrence

B = Baseline Studies
M = Monitoring Studies

3.8.4 Impact Analysis and Monitoring

Certain wildlife inventory and monitoring data, mainly elk and mule deer home range and movement information, collected during extensive, long-term studies were analyzed using analytical procedures available at Los Alamos Scientific Laboratories. These computer analyses used locational (coordinate) information from the extensive telemetry studies of radio-collared big game animals to plot individual animal locations over time and thereby define seasonal home ranges and migratory movements within and between ranges. A comparison of home ranges between animals from the mine site with those outside of mining influence showed no discernable differences. In addition, the inference was made that because animals within lower elevational habitats (location of the mine site) had larger home ranges, loss of small areas due to mining would not have a significant effect on mine area animals. Interpretation of the results by Mine G and Los Alamos personnel was complicated by the lack of actual premining baseline data and a perceived need for more monitoring data. However, according to Mine G's wildlife consultant, one conclusion of the analysis was that there were no discernible effects. Supplemental work in 1982 indicated that elk become habituated to mining activity. With respect to mule deer, the study concluded, there was no observed relationship between animal movements and mining activity. However, mine personnel pointed out that effects of mining activity on deer may be too subtle to be detected by telemetry and observation of gross movement patterns.

An additional Los Alamos modelling effort was undertaken to predict small mammal populations in the mine and adjacent areas. In this instance, one model scanned the mine generated data and selected the most appropriate population estimating model for use with this data. The selected model indicated that small mammal trapping data were insufficient to predict populations and causes of fluctuations in the populations. According to mine personnel, this insufficiency was due to the small numbers of animals captured which were insufficient to satisfy minimum data requirements of the model.

No other analytical impact assessment procedures were attempted with mine-generated wildlife data. Remaining impact assessments were made by intuitive judgement of the potential effects of the mine on wildlife and needs for reclamation and mitigation. Information used for these intuitive assessments included: quality of adjacent habitats; presence or absence of suitable habitat for a given species; observed animal distances from the operation; and the ability of varies species of wildlife to adapt to new environmental conditions. In some instances, direct observational studies were conducted to support intuitive assessments. For example, the occurrence and frequency of elk pellet-groups in sample plots were used as an indicator of elk use of reclaimed areas. In other instances, certain data such as for small mammals, passerines, herpetofauna, fish, and aquatic invertebrates were not used by Mine G personnel even in the intuitive evaluation of impacts or mitigation needs.

3.8.5 Mitigation Planning

As discussed in the introduction to Chapter 3.0, Mine G is in compliance with existing wildlife performance standards (30 CFR 816.97).

Other than compliance with these standards and the surface owner's requirement for return of wildlife habitat following mining, additional mitigation and reclamation for wildlife has been initiated by Mine G on their own accord.

Efforts implemented by Mine G can be segregated into two subsets: specifically-designed mitigation techniques, and alternate reclamation practices developed to improve specific habitat components beneficial to wildlife. The first subset, mitigation techniques, includes such practices as: 1) construction of rock piles placed randomly within reclaimed areas as small mammal shelter and escape cover and as perch sites for birds and raptors; 2) formation of brush piles to provide habitat analogous to rock piles; 3) fencing of the entire permit area to exclude livestock, which could compete with certain wildlife species for forage, trample important riparian vegetation, and compact streamside soils; 4) establishment of cavity nesting habitat (nest boxes) for kestrels; 5) fertilization of offsite habitats to improve forage production for big game; 6) education of mine personnel about the effect of wildlife harassment in an effort to reduce purposeful or inadvertant destruction or harassment of wildlife; and 7) introduction of stocked fish into mine-area ponds as a "barometer" of water quality and to provide prey for fish-eating avian and terrestrial predators.

The second subset involved alternate reclamation practices designed to improve specific habitat components beneficial to wildlife. These reclamation practices involved: 1) leaving a short highwall; 2) redistribution of soils in a non-uniform manner, leaving thin rocky soils on slopes and thicker soils on ridgetops and valley bottoms; and 3) selection of vegetation species for the revegetation seed mix in an attempt to reestablish early successional floral communities of benefit to local wildlife. These specific habitat components were deemed by the operator to be important for the successful return of the required post-mining land use of wildlife habitat, and the state regulatory authority approved them following the initial justification provided by the mine operator. Since Mine G does not involve Federal coal or surface and since these practices were considered to be consistent with pre- and post-mining land use, they were not desigated as "Experimental Practices" and were, therefore, not subject to review and approval by OSM.

The short highwall was allowed because it was stable, and it resembled rock outcrops and bluffs that are a natural feature of the existing landscape. Topographic diversity provided by such outcrops creates a variety of ecological niches important to many species of wildlife. The varied redistribution of topsoil encourages a diversity of plant species and floral communities which is vital for the reestablishment of a variety of wildlife. Early successional revegetated plant communities are important to wildlife because these communities provide a greater diversity of habitats and often greater forage production than do climax communities. Although, in the long-term, these communities will evolve toward climax plant communities, they do provide the benefits of habitat diversity and increased forage production to wildlife over the short- and intermediate-term. The revegetation plan also incorporated efforts with regard to reestablishment of shrubs and trees, especially in configurations beneficial to wildlife, such as travel lanes and mixing of types for edge effect.

3.8.6 Success Determination Methods

No analytical methods are being used to evaluate the validity of impact assessment procedures. However, general qualitative analysis and direct observational assessment by Mine G personnel, based on monitoring information, suggest that negative impacts to big game are not occurring or are too subtle to be detected.

For evaluation of mitigation success, qualitative observations by mine personnel of animal utilization of reclaimed areas and sedimentation ponds have been used to assess reclamation success. For example, monitoring data from pellet-group surveys indicate use of reclaimed areas by mule deer and elk. In most instances, however, insufficient time has passed to allow even a qualitative evaluation of mitigation techniques or reclamation success.

3.8.7 Summary of Identified Concerns or Problems

Mine G's major concern with respect to reclamation for wildlife is the successful establishment of the proposed post-mining land use of wildlife habitat in accordance with the surface owner's desires. The effectiveness of implemented reclamation and mitigation techniques cannot be fully evaluated yet because insufficient time has passed since mitigation was initiated. However, certain evidence of wildlife "reinvasion" of mined areas (such as the presence of elk pellet groups) is beginning to become apparent, especially on the mine's oldest reclamation (1969). But, additional comparisons with adjacent undisturbed areas must occur before definite opinions can be offered.

3.9 Mine H

3.9.1 Description of Appropriate Site Characteristics and Information

Mine H is located in northwestern New Mexico and has been in operation since 1973. Coal is mined by a combination dragline and truck-shovel operation and transported to a mine-mouth power-plant. The climate of the area is arid, averaging 6.6 inches of precipitation and over 50 inches net evaporation loss annually. Both diurnal and seasonal temperatures are moderate and winds average about 6 miles per hour from an easterly direction.

Premining land uses were grazing, gravel and fill removal, oil development, and wildlife habitat. Post-mining land uses as determined by the operator, will be grazing, oil and gas development, wildlife habitat, and recreation. The topography is level to nearly level, with occasional outcrops of rock, and is drained by several flat and broad channels typical of the area. Four distinct habitat types occur in the permit area: grassland, shrub/grassland, greasewood arroyo, and talus slopes. Warm season grass species and shrubs are the dominant plants occurring in these habitat types.

3.9.2 Focus of Wildlife Concerns

The mine site is not considered an important area for any species of big game according to the New Mexico Department of Game and Fish. Pronghorn are an occasional visitor to the area but are not common. In addition, no federally listed threatened or endangered or state sensitive species were determined to exist on or near the area during baseline studies. A few raptors have been observed hunting or perching within the area but no nests, active or inactive, were found. A variety of small mammals, songbirds, reptiles, and amphibians were documented from the area's habitats, and qualitative observations identified four species of upland game birds (two species of quail, ring-necked pheasant, and mourning dove).

Because no economically, ecologically, or legally important species of wildlife are found on the mine area, mine personnel did not identify any special wildlife concerns.

3.9.3 Methods and Data

Baseline data collection for wildlife first occurred in 1980, seven years following the initiation of mining. Investigations were relatively comprehensive for those species of wildlife and associated habitats existing on the mine area. Baseline studies did not identify any critical habitats or habitats of unusual value at the mine. The methodology and data obtained are summarized in Table 13.

TABLE 13

Wildlife Methods and Data Collected
for Species Groups at Mine H

Species Group Methods	When Used	Data Collected
Big Game		
Strip Transect	B	Relative Abundance, Distribution, Habitat Affinity
Incidental Sighting	B	Species Occurrence
Medium-sized Mammals		
Incidental Sighting	B	Species Occurrence, Relative Abundance
Small Mammals		
Trapping	B	Species Occurrence, Relative Abundance
Raptors		
Ground Observation	B	Unique Habitat Features, Species Occurrence
Upland Gamebirds		
Incidental Sighting	B	Species Occurrence
Songbirds and Others		
Strip Transects	B	Species Occurrence, Relative Abundance, Habitat Affinity, Species Diversity
Qualitative Obs.	B	Species Occurrence, Habitat Affinity
Reptiles and Amphibians		
Strip Transects	B	Species Occurrence
T, E, & Sensitive		
Night Spotlighting	B	Ferret Occurence in Prairie Dog Town
Incidental Sighting	B	Species Occurrence

B = Baseline Studies
M = Monitoring Studies

3.9.4 Impact Analysis and Monitoring

Based on permit application documents, baseline data were used to satisfy regulatory requirements and for an intuitive assessment of impacts due to mining. No analytical assessments were used, although much of the data collected could be used following mining for a qualitative assessment of reclamation success. According to permit documents, Mine H has committed to an annual wildlife monitoring program that will consist of: 1) "opportunistic sightings of large mammals and raptors"; 2) "periodic (unspecified in the application) night surveys for predators"; and 3) "periodic small mammal trapping". This program is designed to provide information for qualitative characterizations of wildlife use of reclaimed areas.

3.9.5 Mitigation Planning

Wildlife mitigation at Mine H consists mainly of compliance with the wildlife performance standards as presented in the federal regulations (30 CFR 816.97). For example, all power transmission structures will be constructed or retrofitted to prevent electrocution hazard to raptors. Stockponds that existed prior to mining will be replaced.

The only habitat enhancement mitigation technique employed at Mine H is the random placement of rock piles on newly-reclaimed areas in an effort to mitigate the loss of talus slope habitat. Mine H personnel expect these rock piles to serve as shelter for small mammals, perch sites for raptors, and potential denning locations for predatory mammals such as coyote, grey fox, and striped skunk.

3.9.6 Success Determination Methods

Currently, no mitigation success determination procedures are being used at Mine H. However, data from the proposed monitoring program are expected to be used to make an intuitive evaluation of reclamation success with respect to replacement of wildlife habitat at some future date. For this evaluation, the monitoring data will be compared qualitatively to the baseline information.

3.9.7 Summary of Identified Concerns or Problems

No significant wildlife reclamation problems or concerns have been identified by Mine H personnel or the state regulatory agency.

3.10 Case Study Summary

A summary of major issues and the animal groups or species affected for each case study presented is given below:

	Animal Groups or Species Emphasized	Issues
Mine A		
	Waterfowl, Upland Game Birds	Replacement of Wetlands and Native Prairie
Mine B		
	Upland Game Birds, Songbirds, Big Game	Replacement of Woody Draws
Mine C		
	Sage Grouse, Big Game,	Relocation of a Strutting Ground, Big Game Habitat Replacement, Avoidance of Riparian Habitat
Mine D		
	Golden Eagles and Other Raptors	Variance from AOC to Leave Highwall, Relocation of Eagle Nests
Mine E		
	Elk, Raptors, Upland Game Birds	Disruption of Elk Calving Activity and Loss of Calving Habitat, Disturbance of Raptor Nesting Activity
Mine F		
	Big Game, Raptors, Upland Game Birds	Post Mining Land Use Design, Big Game Habitat Replacement
Mine G		
	Big Game	Big Game Habitat Replacement,
Mine H		
	None	None

4.0 ANALYSIS

4.1 Chapter Introduction

This chapter begins with a discussion of why various statistical and analytical techniques and models similar to those used for other technical disciplines generally have not been practical or successful in the wildlife discipline for in-depth analyses to support impact assessments and mitigation success determinations. This chapter then discusses the applicability of existing baseline and monitoring data to impact assessment, formulation of mitigation measures, and mitigation success determination. As a part of this discussion, the actual uses of wildlife data are addressed. In addition, areas where redundancy in data occurs are identified, and suggestions for reducing redundancy as well as for improving the availability of existing data are presented.

4.2 Evaluation of Impact Assessment and Mitigation Success Determination

4.2.1 General Difficulties Associated with Measurement of Wildlife Populations

To give some perspective on the problems involved with wildlife reclamation, some of the inherent difficulties of the science of wildlife biology as well as restrictions that current coal mining regulations have placed on wildlife reclamation must be examined. In comparison to most other disciplines, wildlife presents three unique problems. First, most other physical and biological environmental factors have significant effect upon wildlife, especially in the short-term, whereas the opposite usually is not true. For example, the existance of water in some form is critical to all species of wildlife; however, wildlife has little influence over the existance of water. In the case of vegetation, wildlife can have some influence over the presence and extent of floral communities; however, the establishment of vegetation, from a reclamation standpoint, is not dependent on the presence of wildlife. On the other hand, the establishment of specific wildlife populations is ultimately dependant on the presence of appropriate vegetation communities. Second, the effects of a changing environment on wildlife often are difficult to perceive and quantify as many wildlife species exhibit various propensities for adaptation. The ability to adapt has not yet been explored fully by the science. Third, the mobility of most wildlife presents difficult problems with respect to measurement of wildlife populations over time.

The basic response of wildlife, both of populations and of individuals, to various environmental factors is often easy to predict intuitively but usually very difficult or impossible to quantify. For example, a severe winter storm will have adverse effects on most wildlife species, but predicting the total extent of these effects is impossible. In addition, it is extremely difficult to segregate sources of influence or variation and to determine which factors have caused what percent of the effect.

Even when a source of impact on a wildlife population can be isolated from the other factors that affect that population, the degree of impact often is difficult to determine due to the inherent capability of wildlife populations to adapt to a changing environment. For example, the effect on the population of the loss of one road-killed mule deer is relatively easy to assess; some percent mortality. However, assessing the impact of 100 acres of lost habitat is not nearly so straight-forward. Displaced animals may be able to find new habitat nearby that is not filled to carrying capacity, or they may adapt to a newly reclaimed area.

Animal movement in response to changing environmental conditions points out the third complication involved with measurement of wildlife parameters - the mobility of wildlife. Where point-in-time areal measurements may often suffice for other disciplines such as soils and vegetation, wildlife measurements must occur over a much larger area and time frame. For example, the number of pronghorn on a large unit of land can change from day to day and area to area. A point-in-time measurement on a single area may yield zero animals or 100 animals depending on the size of the area measured or where the animals were at the time of measurement. This creates the problem of which number should be used as baseline data. As a result, long-term monitoring often is required for population estimates.

Beyond the difficulties of the science, SMCRA contains provisions that affect the ability of operators to provide for wildlife mitigation. The basic building blocks for wildlife habitat (water, soil, vegetation, and topography) are controlled very strictly in an attempt to prevent excessive erosion, unstable land forms, and unsound conversions of vegetation communities and land use. However, when these disciplines are strictly regulated to prevent such problems, the inherent habitat diversity found in natural systems, upon which wildlife are dependent, can be lost to some degree.

4.2.2 Specific Difficulties with Impact Assessment and Mitigation Success Determination

Because of the general difficulties with the science, biologists, involved with wildlife reclamation, most often use qualitative evaluations to assess impacts. Qualitative or semi-quantitative evaluations also are used most frequently for mitigation success determination. These qualitative evaluations are founded on intuitive professional judgements based on well-established and proven ecological principles. For example, various kinds of quantitative and qualitative baseline and monitoring data collection methods are used by several western mines to determine wildlife use of the mine and adjacent areas. These data typically are not analyzed statistically, but,rather, are reviewed carefully by industry and agency biologists for intuitive assessments of population trends, wildlife habitat preferences, habitat quality, and other information used for impact assessment. More specifically, quantitative small mammal and songbird population and diversity baseline data very often are reviewed by the regulatory authority and state game and fish agency as a measure of habitat quality. In fact, because habitat quality can be assessed in other, more practical manners, several states no longer require this particular kind of quantitative data or have reduced required efforts.

This intuitive approach has not always been used because some impact assessment methods were thought to lend themselves to mathematical interpretation. When SMCRA was first promulgated, many attempts were made to study wildlife groups intensively in an effort to evaluate populations and mining impacts quantitatively. Several of the studies identified in Chapter 3.0 of this report provide examples of efforts to segregate the various influences on, and to define, animal populations.

Mine C's work with small mammals involved extensive trapping over all habitats and quantitative estimates of population size and diversity for a period of six years in an attempt to isolate and/or predict small mammal population behavior. The final result of this effort, as reported in the permit application, was the determination that the variation of small mammal populations, due to natural causes such as climate, so overwhelmed other sources of variation that accurate predictions of man-induced effects were futile. Following this determination, small mammal monitoring efforts at Mine C have been reduced and appear to be used only as an indication of habitat quality.

Another example involves Mine G's wildlife monitoring efforts. In the case of the small mammal data, Los Alamos Scientific Laboratory's attempts to model the animal populations indicated that too few animals exist within the natural system to allow the model to function properly. A study recently funded by the OSM quantitatively evaluated the effectiveness of mitigation measures used on coal mining operations in western states. This study, conducted by Thorne Ecological Institute (Stoecker et al. 1984) analyzed the relationship between habitat features and wildlife communities at four surface coal mines in Wyoming and Montana. The study used multiple linear regression analyses to identify the relationship between various wildlife populations (rabbits, small mammals, big game, songbirds and upland gamebirds) and habitat features of reclaimed areas. Wildlife variables such as species diversity and abundance were compared to habitat variables such as shrub cover, distance to water, and undulating topography. One of the principal conclusions of this study was that wildlife responses to various habitat features and configurations was consistent with common professional intuitive judgement. For example, big game use of reclaimed surfaces was positively correlated to shrub cover; and ponds, rock piles, adjacent habitat complexity, vegetation complexity, total vegetation cover, and forbs were important to small mammal diversity and abundance.

In certain instances, baseline and monitoring efforts have used quantitative assessments in conjunction with descriptive and/or direct observational data to evaluate impacts and determine mitigation procedures. Examples of such semi-quantitative work include Mine C's and Mine E's multi-year telemetry studies of sage grouse and elk, respectively. At Mine E, monitoring by radio-telemetry documented the lack of any measurable impact to resident elk populations. At Mine C, monitoring by radio-telemetry and observation of marked birds documented a change in breeding sage grouse fidelity from an historic lek to a new man-made strutting ground.

Semi-quantitative assessments can vary along a continuum from mostly analytical procedures such as telemetry studies and mortality counts to mostly descriptive procedures such as direct observational information. Examples of direct observational information include determination of: breeding success (e.g., fledging of young raptors near major disturbances); habitat utilization (e.g., animal presence within specific habitats); and mitigation success (e.g., occupancy of artificial nesting structures).

As discussed in Chapter 2.0 most state regulatory agencies are placing more emphasis on the evaluation of habitat and less emphasis on total species counts and population numbers. However, some states still require mines to collect quantitative data for all species groups for a qualitative evaluation of habitats on the mine area. Where concern for specific issues arise, such as big game populations, upland gamebird breeding grounds, elk calving habitat, wetlands, and woody draws, all states still may require quantitative data on populations, animal distribution and utilization of habitats .

4.3 Baseline and Monitoring Data Evaluation

4.3.1 Uses of Wildlife Data

As discussed in the previous methodology section, the primary current uses of wildlife baseline and monitoring data are for qualitative and semi-quantitative assessments of habitat quality and intuitive assessments of projected impacts and mitigation success. In the past, such assessments have emphasized intensive field studies designed to provide data on actual population size and other associated parameters for a variety of wildlife species. With actual numbers, it was believed that impacts could be quantified accurately and performance standards developed. However, as discussed in Sections 2.4 and 4.2, these quantitative efforts for the most part, have been unsuccessful because they required extensive additional data, or because the natural variation within animal populations overwhelmed the efforts to segregate man-induced sources of variation. Although many of these data are not suitable for analytical assessments, their use for gaining an understanding of local ecological characteristics can be invaluable from a qualitative standpoint. However, performance standards cannot be based on such qualitative judgements as a certain amount of subjectivity potentially can be involved.

Occasionally, certain data are used for more semi-quantitative assessments of potential impacts where such data can be developed using viable methodologies. Information on wildlife species presence, species diversity, and species distribution, in conjunction with information on floral communities and other habitat features, may be used along with professional judgement for semi-quantitative evaluations of habitat quality prior to mining. This information, along with knowledge of the mining operation, can then be used for impact assessment and formulation of mitigation plans.

Another use of quantitative baseline data, according to some industry and several agency personnel, is for potential evaluation of mining impacts in the future. Without baseline data, evaluation of the severity of such impacts might be impossible. Even though the baseline data were suspect due to uncertainties inherent in the techniques or science, future advances in the state-of-the-art may allow compensation for these uncertainties and evaluation of the impacts. At least qualitative comparisons between baseline and post-mining data and intuitive evaluations of impacts could be made. In addition, future comparisons with the baseline data may be required for a determination of success of particular wildlife mitigation measures, supplemental to success determinations specific to other disciplines. Mine B is one example of such a use of baseline data.

In certain instances, data for big game, raptors, and upland gamebirds are being gathered through extensive areal and temporal efforts to address unsuitability designations. Portions of some federal coal lease tracts have been or will likely be designated unsuitable for coal mining due to wildlife concerns. Where conflicting opinions occur between professional biologists about the potential impact of a mine, specific quantitative or qualitative wildlife research has been directed to predict what the impacts might actually be. A variety of past research efforts have provided evidence in support of some designations and against others. For example, in the past, raptor nests were protected by extensive buffer zones. Several studies by mining companies throughout the West have shown that mining can occur, in many instances, quite close to some species of nesting raptors with little or no effect upon nesting success. Other studies such as those at Mine D and mines in the Powder River Basin have shown that raptor nests can be moved successfully, thereby allowing mining of the coal beneath them. A variety of ongoing studies are attempting to determine the nature and extent of mining impacts. More studies will be required to address potential impacts, such as secondary effects and altered habitat among others, of which the severity is unknown.

Many data are not used by the operator for wildlife reclamation after they have been submitted in the mine plan, except as an indirect measure of habitat quality. Data such as small mammal and songbird relative abundance and diversity seem to fit this category. However, it is expected that most, if not all, state regulatory authorities will compare premining small mammal and songbird data to post-mining (near bond release) data for an intuitive evaluation of reclamation success with respect to these animal groups. Therefore, it cannot be said with absolute certainty, that certain data will not be used in the future for wildlife reclamation or success determination.

4.3.2 Redundancy of Data Collection

Collected data are redundant to some extent both within and between states, although there is now less redundancy in data collection than there has been in the past. Generally, baseline data must be collected from each mine because wildlife information is often unique to the location of each mining operation. For adjacent operations, data from one mine occasionally is shared with, or accessed by, the other, especially where unsuitability designations or economically (usually game animals), ecologically (animals important to the function of the ecosystem), or legally important species (those that are protected) are involved. However, because mining operations are in competition with each other, specialized information that has been developed and does not appear in public documents such as the mine plan or permit application may be considered proprietary. In these cases, as well as those where site-specific information must be investigated, certain redundancies of collection may occur, but probably are unavoidable.

Only Wyoming and Colorado have taken steps to compile data from the various industry studies and incorporate this information into existing computerized systems so that it can be accessed by other operators within the state (see Chapter 2.0). These efforts, where they have occurred, are in their early stages.

A greater problem exists between states, apparently due to limited communication among the state regulatory and game and fish agencies. Research work performed in some states is often repeated for similar concerns in others. Some personnel at the OSM's Western Technical Center feel that one of their most significant duties could be to act as a "clearinghouse" for data and research from mine plans and permit applications within their region. Currently, such data is shelved at state and Federal offices and may not include the most current efforts. By making such data available in a more usuable format, non-site-specific information could be shared more easily, and advances made by research could be used to the benefit of all operators and agencies in the western states. Such a clearinghouse would help to ease the overall burden of data collection and to identify areas where research is needed. A computerized data repository linked by a "keyword" index would significantly facilitate access to this information.

5.0 ISSUES, DATA GAPS, AND RESEARCH NEEDS

5.1 Chapter Introduction

This Chapter summarizes major innovations in wildlife mitigation along with the issues and related data gaps identified in the preceding chapters. Research needs and policy options to address these issues or identified data gaps are also discussed. Major innovations in wildlife mitigation are listed and summarized in Section 5.2. Issues and research needs identified by this study are summarized in Table 14 and discussed in Sections 5.3 through 5.8. For the most part, issues listed in Table 14 correspond to or expand on those already raised in previous sections. Sections (5.3 - 5.7) summarize and discuss those issues or research needs believed by the authors to be of greatest importance to wildlife mitigation planning and habitat restoration. The remaining issues identified on Table 14 are listed and briefly discussed in Section 5.8. In certain instances, some of the lesser issues on Table 14 overlap or relate directly to the major issues and are discussed, where relevant, in Sections 5.3 - 5.7.

5.2 Overview of Innovative Mitigation

When coal mine reclamation was first required in the West, a variety of "tried and true" techniques were available to at least partially mitigate impacts to wildlife. Many of these techniques are identified on Table 4. As increasingly stringent reclamation requirements evolved, innovation has occurred. In addition, some proven mitigation techniques

Table 14

Identified Issues and Research Needs1/

Issue or Research Need	OSM	BLM	USFWS	ND PSC	ND DG&F	MT DSL	MT DFWP	WY DEQ	WY DG&F	CO MLRD	CO DOW	NM MMD	NM DG&F	Industry	Private Environmental Groups
Issues															
• Need More Flexibility With Respect to Legal Requirements Regarding:															
- Approximate Original Contour (AOC)			X	X			X	X	X	X	X	X		X	
- Leaving Impoundments			X				X	X	X	X	X	X		X	
- Uniform Topsoil Replacement			X					X	X					X	
- Revegetation Standards (where they impose limits on habitat diversity)			X					X	X	X	X			X	
- Use of Non-native Vegetation Species			X				X				X	X		X	
- Experimental Practices			X			X				X				X	
• Need for Adherence to the Original Intent of SMCRA															X
• Cumulative or Regional Mining & Secondary Impacts			X	X				X	X	X	X	X	X		X
• Post-mining Land Use Conflicts with Wildlife Habitat	X		X	X	X			X	X	X	X	X	X		X
• Monitoring of Post-mining Land Management Practices			X					X	X						
• Lack of Regulatory Follow-up on Implementation of Fish and Wildlife Plan	X		X					X	X						
• Loss of Woody Vegetation			X	X								X			X
• Need for Interdisciplinary Involvement for Wildlife Mitigation Planning	X		X				X								
• Need for Wildlife Mitigation Planning Early in Permitting Process	X		X												X

Table 14 (continued)

Issue or Research Need	OSM	BLM	USFWS	ND PSC	ND DG&F	MT DSL	MT DFWP	WY DEQ	WY DG&F	CO MLRD	CO DOW	NM MMD	NM DG&F	Industry	Private Environmental Groups
• Wildlife Habitat Mitigation Planning Is Often Secondary to Other Discipline Regulations	X		X					X	X	X					
• Standardized Implementation of Unsuitability Criteria		X	X				X								
• Rapid Turnover in State Regulatory Agency Personnel	X													X	
• Unequal Implementation of State Requirements														X	
• Conflicts Between Regulatory Requirements (SMCRA vs. Bald Eagle Protection Act)			X											X	
Research Needs															
• Long-range Monitoring and Research to Assess Impacts or Mitigation Success	X	X	X	X		X		X	X	X			X	X	X
• Need to Develop Habitat-Reclamation Standards Unrelated to Vegetation (including economics)	X		X	X		X		X	X	X			X		
• Need for Compilation or Clearinghouse for Baseline, Impact, and Mitigation Data	X									X					

1/ This table is not intended to be an all-inclusive listing of agency and industry wildlife concerns. Nor does the lack of a check-mark indicate that a particular category is not a concern of a particular group. The table was compiled on the basis of unsolicited agency and and industry responses to the standard interview forms (Appendix A)and from comments provided by private environmental interest groups. We do believe that the number of checks for a particular category does provide an indicator of the relative level of interest or concern about a particular issue or research need across the reclamation community.

were upgraded to address new problems. These innovative and upgraded techniques were illustrated by the case studies presented in this study and are summarized below.

Relocating Raptor Nests.

Relocation of eagle nests is handled as a variance from normal permitting requirements under the supervision of the USFWS, and usually requires a significant amount of coordination and effort by all parties involved to implement the procedure. This mitigation is occurring more frequently than in the past, especially in Wyoming, and has proven to be relatively successful; however, some additional research may be needed. The USFWS is currently working on formalizing standard guidelines for moving raptor nests.

Highwall Development.

Leaving highwalls for raptor habitat is occurring infrequently (one case in Montana and one in Wyoming) and only as an experimental practice. Because of the requirements for experimental practices, significant coordination and effort is required from all parties to implement the procedure. Preliminary indications seem to show the technique to be successful, but much additional information is still needed.

"Architecturally Designed" Post-mining Land Use.

A carefully designed post-mining land use, which returns pre-mining acerages of various land uses to the most appropriate post-mining landforms, occurs infrequently (of the eight case studies, only Mine F had utilized this innovative practice). The procedure is implemented through normal reclamation planning or as a variance. Preliminary indications seem to show the technique to be successful; however, additional time and information is needed to determine if this approach will reduce the potential of landowner misuse or conversion of post-mining lands.

Relocating Strutting Grounds.

The relocation of sage grouse strutting grounds is handled as a variance or permit condition and is usually conducted in cooperation with the state game and fish agency. Significant effort is required to implement the technique and it has met with variable success to date. Mine C found the procedure to be successful, while another attempt in Wyoming was not (Tate et al. 1979). Additional research may still be needed on this technique.

Wetland Reclamation.

Wetland reclamation at Mine A is utilizing a multidisciplinary approach for reestablishment and determination of success. At present guidelines for replacement and standards for success are still being formulated, and it will take several years to determine if efforts have been successful.

Woody Draw Reclamation.

Woody Draw reclamation at Mine B has been occurring for approximately seven years. At present guidelines for reclamation procedures and standards for success are still being formulated and the effectiveness of the technique will take several more years to evaluate. Further details can be found in the companion Vegetation Report (Appendix C).

Shrub Establishment.

Diverse stands of shrubs are of extreme value to wildlife for a multitude of reasons. A variety of new and innovative approaches to the establishment of this aspect of wildlife habitat have occurred and have been presented in the companion Vegetation Report (Section 4.3.2.6).

Live Topsoiling.

Live topsoiling has been found to be a very effective means of reestablishing a diverse vegetative community which in turn is very important for attracting a diverse wildlife community. Innovations which have occurred in this area are presented in the companion Vegetation Report (Section 4.3.2.1) and Soils Report (Section 5.2.2).

5.3 Legal Constraints

A common problem voiced by almost all wildlife agency and industry personnel was that inflexibility in existing surface mining regulations inhibits experimental practices and innovative procedures for wildlife habitat reclamation or enhancement. This problem relates directly to another concern identified on Table 14 that wildlife habitat mitigation planning often is considered to be of secondary importance compared to the enforcement of reclamation regulations for other technical disciplines. Often specific regulations such as those that address the retention of permanent impoundments, return of the land to approximate original contour (AOC), revegetation and land use requirements (e.g., replacement of premining vegetation and land uses is not always best for wildlife habitat), and the use of non-native plant species prohibit or limit the development of features known to be beneficial for wildlife habitat. For example, revegetation requirements usually prohibit the use of an introduced vegetation species even when such a species has proven value for wildlife and is present as well-established populations in adjacent areas. Similarily, in some situations, leaving a highwall with non-uniform placement of topsoil and rubble at its base could increase floral and topographic diversity to the benefit of wildlife. Establishment of such features, however, usually is precluded by requirements for return to AOC, uniform topsoil replacement, and minimum standards for vegetation cover and productivity.

In many areas of the West, suitable cliff-nesting habitat is a limiting factor to certain raptor populations. In these areas, permanent highwalls with appropriate aspect and ledges or cavities would provide valuable nesting habitat. As discussed in the case study Mine D (Section 3.5), certain raptor species will nest readily on suitable highwalls. Aside from providing raptor nesting habitat, a highwall can provide topographic diversity in relatively level areas such as the Powder River Basin, help return pre-mining topography in rimrock areas, and aid in the accumulation of additional surface moisture near the highwall base. The highwall left at Mine G is an example of an effort, not to provide raptor nesting habitat but, to match the pre-mining topographic diversity and landform. Highwalls, along with rock and rubble piles, provide greater structural and floral diversity significantly beneficial to wildlife habitat. The historic inflexibility of regulations against leaving permanent highwalls is being relaxed slowly in some states in a few situations, but a lack of interdisciplinary coordination and information exchange about the potential benefits of highwall retention, among other problems, slows the approval process.

One means of resolving legal constraints on habitat reclamation would be for the regulatory authorities to be more flexible in approving variances from existing regulations when justified by post-mining land use, legitimate wildlife habitat considerations, and thorough planning and analyses. This would mean that requirements and needs of other disciplines would still have to be met for such important issues as mass stability, erosion, and sedimentation control as well as the requirements and needs of operational and engineering constraints. With increased flexibility, more measures beneficial to wildlife habitat could be implemented.

It should be understood that experimental practices have been implemented at some western surface coal mines, as illustrated by case study D. However, these kinds of variances and experimental practices are not common because applications are granted infrequently as a result of regulatory inflexibility, inadequacies in the application, or lack of proper justification for the practice. In additon. a common industry complaint regarding experimental practice applications is that the time and effort usually required for regulatory review and/or approval is often extensive and is, therefore, costly to the operator in terms of time and money. Both industry and fish and game agency personnel interviewed indicated that many possible opportunities for variances and experimental practices have never been proposed because of the mining companies' perception of the time and effort required for approval by the regulatory authority.

Where variances from regulations governing environmental concerns such as AOC and uniform replacement of topsoil have been allowed, the regulatory authority has determined that these variances and experimental practices have not overly compromised the replacement of other environmental features. However, private environmental interest groups have expressed the concern that variances and experimental practices of this nature may negate the original intent of SMCRA.

5.4 Long-Term Monitoring and Research

As discussed in Chapters 2.0 and 3.0, professional judgement, based on a knowledge of the ecological characteristics of an area and the operational aspects of a proposed mine, is the principal means used to assess impacts and formulate mitigation plans. Most state game and fish agency personnel interviewed indicated that this approach usually is adequate considering the general lack of practical and applicable analytical techniques available for these assessments. However, the majority did feel that there was a definite need for long-term monitoring and research to validate these intuitive assessments and evaluate the success of implemented mitigation measures. In most situations it will take several years, if not decades, for a complete evaluation.

5.5 Post-mining Land Use Conflicts

Another major concern expressed by industry and regulatory agency personnel was the lack of a regulatory mechanism for implementing wildlife mitigation measures where the proposed primary post-mining land use is subtly changed from a pre-mining land use of wildlife habitat to other uses. In these situations, reclamation for wildlife habitat features is often in conflict with the land management objectives of the landowner or manager, and is therefore, not considered. This situation often arises in states where reclamation standards for land proposed for wildlife habitat (e.g., woody plant density standards, and overall vegetation diversity) are more difficult to attain than those required for lands proposed for other uses such as rangeland or pastureland.

A side issue related to post-mining land use also was identified by the USFWS, one mine operator, and nearly all fish and game agency personnel. This issue concerns the lack of a regulatory mechanism to encourage or enforce proper post-mining land management practices subsequent to bond release. The concern here is that even the best reclamation efforts can be negated by improper post-bond release land management. From a wildlife standpoint, this concern primarly relates to those lands such as pastureland and rangeland where wildlife habitat is usually a secondary or coincidental land use. For example, even though the mix of species selected for revegetation favors targeted wildlife species, lack of implementation of proper land management practices following mining can result in a reduction of beneficial shrubs and overall vegetational diversity.

The problems of conflicting land uses, post-mining land use conversion, or improper post-bond management may be addressed by careful landscape design for the return of land uses that minimize the potential for land conversions following reclamation by matching land use to the best possible landform for that use. Such design would necessitate more detailed descriptions of post-mining land use, thereby encouraging additional thought and care in the implementation of reclamation techniques and management. Mine F serves as an example of such a landscape approach to land use design. The lower elevational land that, prior to mining, was mostly agricultural is being returned to agriculture where the slope is less than 12 percent. All land below a particular elevation that is steeper than 12 percent is being returned to grazing land. Finally, all land above the particular elevation (and also broken topography wherever it occurs) is being reclaimed to wildlife habitat. Prior to mining, all non-agricultural lands supported the coincidental uses of grazing land and wildlife habitat. In this manner, the approximate acreage of each pre-mining land use is being returned; however, the placement of each post-mining land use is "architecturally designed" to maximize the utility of all reclaimed lands as a unit.

5.6 Habitat Reclamation Standards Not Related to Vegetation

As discussed in Chapter 2.0, there is a general regulatory trend, in most states, away from collection of quantitative wildlife data such as counting species and numbers of animals toward more emphasis on describing and delineating habitats. In addition, qualitative or descriptive animal data is being used more frequently as an indirect measure of habitat quality and diversity. Because of these trends, both agency and industry personnel are increasingly aware of the need for measurements and/or descriptions of wildlife habitat features that go beyond measurement of vegetation parameters.

As discussed in Chapter 4.0, many wildlife habitat requirements relate to an area's physical features such as topography and surface water, in addition to its floral components. Because of this, habitat descriptions must include measurements of physical features such as the size, distribution, and frequency of rock outcrops or the overall variety in topographic relief. In addition, research is needed to identify the physical features that are most important to given species of resident wildlife and to develop practical design criteria for use in reestablishing these features during reclamation. Currently, habitat reclamation focuses on replacement of floral attributes and very seldom stresses replacement of physical characteristics or features of the land. AOC regulations require the replacement of gross topographic features; however, certain large features such as escarpments as well as most micro features such as erosion gullies, rubble piles, and minor depressions often are lost during the restoration of AOC. Principal reasons for the lack of focus on replacing these kinds of physical features are: 1) no regulatory mechanism for replacement of minor physical features; 2) little or no flexibility from non-wildlife discipline standards such as AOC, floral cover and productivity, and erosional stability; 3) little understanding of which physical features are most important for wildlife; and 4) technical and economic limitations on replacement of many physical features.

Another common issue raised by most regulatory personnel was the need to develop practical design criteria for many of the more commonly recommended wildlife habitat mitigation features such as rock piles and shrub clumps. The general lack of design criteria for wildlife habitat reclamation and enhancement measures has been identified by regulatory personnel as a major deficiency in current wildlife mitigation planning. Because of this deficiency, wildlife habitat reclamation and enhancement commitments found in most Fish and Wildlife Plans usually lack specificity for implementation. Such commitments are, therefore, difficult to enforce by the regulatory agencies. The lack of proven design criteria also makes it difficult for game and fish agency personnel to defend requests for implementation of specific wildlife mitigation procedures (such as placement, composition, and configuration of shrub clumps) to mine operators or to regulatory authority personnel in the other more analytical disciplines (e.g., hydrology, vegetation, and soils). If design criteria were available for habitat reclamation features and enhancement measures, standard success criteria also could be developed by both game and fish agency and regulatory authority personnel for use in evaluating wildlife reclamation success. However, implementation of such criteria must remain somewhat flexible and be cognizant of operational and land use contraints.

Research is needed to correlate the needs of different wildlife species to various topographic features as well as to the discrete physical features that may be reclaimed - shrub patches, rock piles, impoundments, highwalls, and drainages, among others. This research also must address ways in which the design (e.g., size, configuration), distribution, density, and location of these features affect wildlife.

Another research need is the development of economic information related to the implementation of wildlife habitat reclamation and enhancement measures. Many measures may offer economic benefits to the operators such as reduced backfilling costs that would provide a strong incentive to reclaim for wildlife habitat. One possible means of demonstrating these benefits would be to develop a handbook summarizing specific design criteria and associated costs for accepted habitat reclamation and mitigation measures. Much of the initial design criteria included in such a handbook could be provided by professional judgement and existing literature, and then refined and updated as additional information becomes available.

5.7 Cumulative, Regional, and Secondary Mining Impacts

A major concern expressed by many game and fish agency and regulatory authority personnel is the lack of provisions in SMCRA to address cumulative and regional surface mining related impacts to wildlife, particularly secondary impacts that result from the influx of mine personnel and associated urbanization. Many game and fish agency personnel believe that secondary impacts to wildlife are of greater magnitude than those related directly to mining. While mining may disturb habitats temporarily, secondary impacts can be more permanent. Secondary impacts are of greatest concern where regional mining development has occurred, and the resulting influx of workers has been significant. Housing, schools, transportation networks, and other support facilities eliminate wildlife habitat on a long-term basis, if not permanently. In addition, population increases in rural areas cause increases in hunting pressure (legal and illegal), wildlife harassment (intentional and unintentional), and the potential for wildlife road-kills.

Currently, SMCRA wildlife regulations (30 CFR 816.97), unlike the NEPA (National Environmental Policy Act) process, do not specifically require an assessment of cumulative, regional, or secondary impacts or the implementation of mitigation measures for these impacts. According to one game and fish agency biologist, even previous NEPA-triggered environmental impact statements for regional coal development made little attempt to quantify regional secondary impacts to wildlife. Environmental impact statements for regional coal development did make impact projections based on regional scenarios, but little regional monitoring or research has been conducted to validate these projections. According to game and fish agency personnel interviewed, only one regional wildlife impact monitoring study has been implemented - the Powder River Basin cooperative pronghorn study. As a result of this research gap, regulatory authority personnel identified a need for studies at the Federal level to address the significance of regional mining and related secondary impacts.

5.8 Other Issues

5.8.1 Lack of Regulatory Follow-up on Wildlife Mitigation

A concern raised by the OSM, USFWS, and Wyoming agencies was that there is minimal regulatory follow-up to assess an operator's compliance with mitigation commitments made in the permit application's Fish and

Wildlife Plan. They believe that this situation arises from the general lack of specific design or success criteria for many wildlife mitigation measures (see Section 5.6). Also, in some areas, mine inspectors may not have sufficient wildlife training or background to assess operator compliance with wildlife mitigation commitments.

5.8.2 Need for Interdisciplinary Approach and Early Planning

Another identified concern is that wildlife mitigation plans often are not formulated until long after the Mining and Reclamation Plan is developed. The need perceived by OSM and USFWS here is that wildlife and habitat mitigation plans could be improved through more early planning and consultation with representatives of other technical disciplines before final mining and reclamation plans are developed. The dependence of wildlife habitat reclamation on other disiplines demands that an interdisciplinary approach be taken during the regulatory review of such plans.

5.8.3 Standardization in Implementation of Wildlife "Unsuitability Criteria"

BLM, USFWS, and state game and fish personnel in Montana indicated a need for more consistency in the implementation of wildlife "Unsuitability Criteria" within the state. These personnel believe that the use of wildlife "Unsuitability Criteria" to prohibit mining in specific areas has not been uniformly applied. Agency personnel in other states indicated that they have not had much need to invoke wildlife "Unsuitability Criteria" for surface coal mining in their respective states. This exemplifies the trend of some states to require wildlife mitigation rather than invoke "Unsuitability Criteria" to exclude specific areas from mining.

5.8.4 Loss of Woody Vegetation

A major concern of regulatory authority personnel in North Dakota and New Mexico was the impact of mining on woody draw and pinyon-juniper habitats, respectively. North Dakota currently is developing guidelines and success standards for replacement of woody draw habitat based on research at Mine B (Section 3.3). New Mexico regulatory authority personnel, on the other hand, are uncertain whether the technology exists to replace pinyon-juniper (a valuable wildlife habitat) after the topsoil and subsoil resources have been disturbed and replaced. In addition, emphasis on replacement of pinyon-juniper will be limited for New Mexico mines, as only one proposed and no existing mines intend to restore pinyon-juniper. In fact, only one existing mine in New Mexico has a proposed primary post-mining land use of wildlife habitat according to the state regulatory authority.

5.8.5 Rapid Turnover in State Regulatory Agency Personnel

OSM personnel and several industry contacts indicated that rapid turnover of state regulatory authority personnel often results in inconsistencies in implementation and enforcement of wildlife regulations.

5.8.6 Unequal Implementation of State Requirements

Industry contacts expressed the belief that the state regulatory and game and fish agencies often are inconsistent in their requirements of operators for special wildlife monitoring or research studies. Industry personnel believed that where research is applicable to several mines in a region, the burden for conducting special wildlife research or monitoring projects should be shared equally.

5.8.7 Conflicts between Legal Requirements (SMCRA versus Bald Eagle Protection Act)

In at least two instances on mines in Wyoming and Montana, situations have arisen where SMCRA regulations are in direct conflict with other federal regulations. An example of this situation was described for Mine D (Section 3.5) where golden eagles established nests on remaining highwalls and the operator was caught between the jurisdiction of two federal regulatory agencies. The Bald Eagle Protection Act, which also protects golden eagles, does not allow disturbance of eagle nests, while SMCRA and state mining regulations require that highwalls be eliminated. In this particular case, the situation was resolved by obtaining approval for an experimental practice to leave one highwall and by successfully relocating nests occurring on other highwalls. This process involved considerable time, consultation with cooperating game and fish agency personnel, and numerous technical plan submittals to the regulatory authority.

5.9 Summary of Research Needs

As indicated in the preceding sections, there is a distinct need for additional research in the areas of 1) long-term assessments of impacts and mitigation success; 2) definition and measurement of physical habitat features important to wildlife; 3) development of flexible design criteria, success standards, and economic analyses for re-establishment of necessary physical habitat features; and 4) cumulative, regional, and related secondary impacts to wildlife. The greatest difficulty with instituting much of this research is the lack of personnel and funds in both government and industry.

One way to address these research needs without additional expense would be to encourage the current trend of de-emphasizing intensive baseline data collection for species groups not emphasized by current impact assessment and mitigation planning. Released manpower and funding could then be redirected toward long-range or regional monitoring and research focused on specific habitat restoration measures. This redirection of effort could be accomplished most easily in coal regions where numerous operations occur in areas with similar habitats and potential impacts to wildlife. A clearinghouse for baseline data, impact assessment information, and mitigation research (as discussed in Chapter 4.0) would make this approach even more viable and eliminate much of the duplication of effort identified by this report. Efforts expended on research and long-term monitoring would need to be shared equitably by operators (and possibly regulatory agencies) so that no single mine is put at a greater economic disadvantage than any other with the same problem. Because coal mines are "not in the business specifically to do research", according to several industry personnel, resistance to additional research and monitoring work could be expected. However, redirected efforts, especially where they could potentially reduce costs to the operators and increase benefits of reclamation, may be considered favorably.

6.0 CONCLUSIONS

The primary purpose of this report was to provide the Office of Technology Assessment with an evaluation of the data and techniques used by industry and regulatory authority and game and fish agency personnel to assess impacts, formulate mitigation, and judge mitigation success for surface coal mining effects on wildlife. In general, a large number of wildlife baseline data (both quantitative and qualitative) are collected, but few analytical techniques are used to assess impacts or evaluate mitigation success, primarily due to limitations of the science of wildlife biology. Wildlife baseline data, in conjunction with knowledge of operational plans, are used primarily for professional intuitive assessments of impacts and formulation of mitigation measures. Baseline data also are used for qualitative and semi-quantitative evaluations of mitigation by making general comparisons between pre- and post-mining wildlife population characteristics, as determined by qualitative and analytical techniques.

The lack of analytical techniques for impact assessment and success determination is related directly to inherent problems with measuring wildlife populations (see Section 4.2.1). Because of these problems, methods that attempt to quantitatively identify impacts or demonstrate mitigation success require considerable effort and expense to implement. For this reason, these intensive methodologies usually are required only where a critical wildlife concern, such as elk calving ground disturbance, is identified. For the majority of cases, wildlife professionals believe that the present use of baseline data along with intuitive assessments and judgement is adequate for impact and mitigation success analysis.

Because wildlife are dependent on specific physical and biological environmental features for their survival, emphasis of most mitigation focuses on habitat replacement. Since wildlife responses to habitat replacement often are difficult to measure, habitat mitigation success normally is indirectly determined by measurement of vegetation parameters.

Several issues and related research needs were identified by this study. The major issues and research needs are as follows:

- Need for long-term research or monitoring for important wildlife concerns to address the validity of intuitive and qualitative impact and mitigation assessments. Because habitat restoration requires a great deal of time, long-term studies are needed to confirm professional intuitive assessments and the effectiveness of implemented habitat restoration measures.

- Need to develop physical or non-floral criteria for habitat restoration and mitigation success assessments. Wildlife are dependent on habitat features other than vegetation. Research is needed to further define what these features are, determine the relative degree of their importance, identify the economics involved with their implementation, and establish criteria for restoration of these features.

- Need for cumulative, regional, and secondary impact assessment. Most studies address site-specific impacts; however, few have attempted any adequate evaluations of regional, cumulative, and secondary impacts related to regional mine development.

- Need for more flexibility in interpretations of state and federal regulations (legal constraints to habitat restoration/enhancement). Regulations directed at minimizing potential impacts associated with other technical disciplines often preclude innovative wildlife habitat restoration and enhancement measures.

7.0 REFERENCES CITED

Office of Technology Assessment. 1984. Environmental protection in the Federal coal leasing program. OTA-E-237, May 1984. U.S. Congress, Office of Technology Assessment. Washington D.C. 154pp.

Stoecker, R. E., R. W. Thompson, R.D. Comer. 1984. An evaluation of wildlife mitigation practices at western coal operations. Final Draft Report. USDI-OSM Contract Nummber J-5120045. Thorne Ecological Institute, Boulder, Colorado 45 pp. and misc. appendices.

Tate, Jr., J., M.S. Boyce, and T.R. Smith. 1979. Response of sage grouse to artificially created display ground. pp 459-463. (In) G. A. Swanson (ed). 1979. The Mitigation Symposium. General Technical Report RM-65. Rocky Mountain Forest and Range Experiment Station, U.S. Forest Service, Fort Collins. 684 pp.

U.S. Fish and Wildlife Service. 1980a. Habitat as a basis for environmental assessment. 101 ESM. Division of Ecological Services, U.S. Fish and Wildlife Service, Department of the Interior. Washington, D.C. misc. pagings.

U.S. Fish and Wildlife Service. 1980b. Habitat Evaluation Procedures (HEP). 102 ESM. Division of Ecological Services, U. S. Fish and Wildlife Service, Department of the Interior. Washington D.C. misc. pagings.

8.0 GLOSSARY

ALLUVIAL TERRACE LANDFORM - A relatively flat topographic feature of the landscape formed by deposition of earthen materials by flowing waters.

ARROYO - A water carved gully or channel in arid areas.

BROWSE - (Noun), Palatable shrubs. (Verb), The act of foraging on shrubs by animals.

CLIMAX BIOTIC COMMUNITY - The final or stable grouping of life forms in a successional series; it is self-perpetuating and in equilibrium with the physical environment.

CONTINENTAL STEPPE - The climate of the northwestern plains states; characterized by long cold winters, hot dry summers, and nearly constant winds.

COULEE - A broad shallow body of water which commonly dries up in drier years.

DANCING GROUND - Small clearings and/or hilltops used by sharptail grouse for their breeding activities; also referred to more generically as a LEK.

DENDRITIC - Branching or treelike form.

DISSECTED PLATEAU - A flat topographic bench exhibiting one or more large erosion gullies or arroyos.

EDAPHIC - Of or having to do with soils.

EDGE EFFECT - The result of the overlap (ecotone) of two adjoining plant communities on the quantity and diversity of wildlife in the immediate vicinity.

EPHEMERAL DRAINAGE - A drainage which carries water for only a very short period of time, usually in response to a rainfall event.

ESCAPE COVER - Floral cover thick enough to provide a visual or physical protective barrier for animals.

FISH AND WILDLIFE PLAN - The management plan for fish and wildlife resources originally required by SMCRA, then remanded by Judge Flannery's decision, then reinstated again - 30 CFR 780.16.

FURBEARERS - A group of animals trapped for the commercial value of their fur as regulated by state game and fish laws (e.g., beaver, fox, mink, etc.) as opposed to small mammals which mainly include rodents (e.g., mice, squirrels, gophers, etc.).

GALLINACEOUS GUZZLER - A wildlife management structure designed to collect and hold runoff water for wildlife drinking water in arid regions.

GAME ANIMALS - A group of animals legally protected under the various game laws of the states, usually taken for human consumption as regulated by hunting laws (e.g., deer, rabbits, ducks, etc.).

GROUND TRUTHING - The on-the-ground process of confirming ecological or environmental interpretations made from aerial imagery or surveys.

HABITAT AFFINITY - The expressed preference shown by a particular species for certain associations of physical and biotic features of the environment.

HERPETOFAUNA - Reptiles and amphibians.

HIGHLAND CONTINENTAL CLIMATE - The climate of the mid-latitude western states at mid-elevational zones; characterized by heavy winter snows, moist springs, and dry summers.

HIGHWALL - The unexcavated face of exposed overburden and bedrock in a surface mine.

INDICATOR SPECIES - A particular kind of animal which, by its mere presence in a given area, indicates the existance of a known associated habitat or habitat feature, lack of disturbance, or other condition; for example, aquatic invertebrates such as mayfly or stonefly larvae indicate unpolluted stream waters.

INTERGRADES - To merge gradually one with another through a continuous series of intermediate forms.

INTERMITTENT DRAINAGE - A drainage which carries water during part, but not all, of a year.

LEK - An assembly area where birds, especially members of the grouse family, gather for display, courtship, and breeding activity.

MEDIUM-SIZED MAMMALS - A group of animals including the largest rodents, all but the largest carnivores, and rabbits and hares.

MESIC DRAWS - Moist drainages exhibiting vegetation somewhat more lush than surrounding land.

MID-GRASS PRAIRIE - An ecoregion in the Great Plains; typified by the group of grass species ranging in height from 6" to 18".

MISSOURI BREAKS - The general dissected plateau area adjacent to, and south of, the Missouri River in Western North Dakota and Eastern Montana.

MODEL - A system of hypotheses, data, and inferences presented as a mathematical description of an entity or ecological situation.

NESTING BOX - A structure built by man for the artificial replacement of cavity nesting habitat. Other nesting structures, such as platforms, are common management tools for aiding avifauna dependent on specific landscape features for nesting success.

OPPORTUNISTIC SIGHTINGS - The occasional observation of a particular animal or environmental feature while a biologist is performing surveys not related to the observation.

OVERSTORY - The uppermost stratum of vegetation in a floral community; usually trees, but can be shrubs.

PASSERINE - Birds belonging to the group of songbirds or perching birds.

PELLET GROUP - The fecal material left by ungulates (deer family).

POPULATION SIZE INDICES - An index which identifies the relative size of a particular species' population without statistically sampling the actual population.

POPULATION ESTIMATES - Actual estimates of an animal's population numbers based on a sample of that population.

PRAIRIE POTHOLE - A regional term for the small wetlands commonly occurring in the glaciated portions of the Northern Great Plains.

RAPTOR - A bird of prey.

REFUGE EFFECT - The tendency for animals to congregate on coal mine properties due to the no trespassing and no firearms policies of many mines, which removes hunting and harassment pressures from big game.

RELATIVE ABUNDANCE ESTIMATES - A determination of the approximate number of animals of a particular species with respect to the approximate number of animals for similar and related species (e.g., species X ranks third among small mammals with 5 percent of all small mammal observations).

RIMROCK - Erosionally resistant rock of a plateau that outcrops to form a vertical face.

RIPARIAN AREAS - Areas exhibiting plants associated with frequent surface or persistent subsurface water such as along the banks of a stream.

SCAT - Technical term for wildlife fecal material.

SCORIA - Burned coal, also known as clinker.

SEASONAL SURVEYS - Surveys which must occur within a particular climatic season or seasons. For example, nesting surveys must occur during the spring.

SEINING - The act of stretching a net across a body of water in an effort to catch aquatic organisms.

SHELTERBELT - A grouping of trees and shrubs usually planted perpendicular to prevailing winds to serve as a windbreak for buildings or to reduce soil erosion in croplands.

SHORT-GRASS PRAIRIE - An ecoregion in the Great Plains; typified by the group of grass species which usually grow to less than six inches tall.

SHRUB STEPPE - A broad floral community of the western Great Plains and foothills of the Rocky Mountains typified by a shrub (usually sagebrush) overstory.

SNAG - An old dead tree, many of which are used by a variety of cavity nesting wildlife.

SNAP TRAPPING - A method of trapping small mammals with typical mouse type snap traps.

SPECIES DIVERSITY VALUES - A mathematically calculated index value which indicates the relative diversity of animals in a given habitat or area.

STATE SENSITIVE SPECIES (OR SENSITIVE SPECIES) - Non-game wildlife species which are rare or have very limited habitat in a particular state and are therefore afforded some degree of protection.

STENOTOPIC HABITAT REQUIREMENTS - Having a narrow range of adaptability to changes in environmental conditions.

STRUTTING GROUND - Small clearings and/or hilltops used by sage grouse for their breeding activities; also referred to more generically as a LEK.

TALUS SLOPE - A slope covered with loose rock.

TELEMETRY - The wildlife management technique involving the attachment of a radio-transmitting collar to animals thereby facilitating their relocation with radio receivers.

THREATENED AND ENDANGERED SPECIES - Any species of animal or plant which falls under the protection of the Endangered Species Act and is listed in the Federal Register. Some states may also have listings that expand the Federal list.

UNDERSTORY - The lowermost stratum or strata of vegetation in a floral community; usually grasses and forbs, but can be shrubs.

WETLANDS - Land containing significant soil moisture and/or free standing water; usually accompanied by a diverse community of riparian and emergent vegetation.

WOODY DRAWS - Broadleaf tree and shrub communities occurring along perennial or intermittent drainages, or bottoms, of more mesic draws and coulees; usually in reference to the northern Great Plains wooded draws.

APPENDICES

APPENDIX A

Interview Forms

APPENDIX A

INDUSTRY INTERVIEW FORM

Operator________________________ Date______________________

Contact_________________________ Phone_____________________

Location/Mine____________________ Interviewer_______________

1) Any data collection, monitoring, or mitigation implemented beyond what is required by the regulatory authority? If so, what are they and why?

2) What outside sources are used or consulted to implement data collection and devise mitigation plans and monitoring?

3) Was collected data used for impact assessment or development of mitigation procedures? If so, how?

4) What mitigation measures are currently being employed and how is their effectiveness determined?

5) Where success standards have not been available how was success of mitigation evaluated?

6) Where wildlife problems have been resolved, what is your (intuitive) evaluation of the cause of success?

mitigation measure

uncontrolled environmental factors

random chance

7) Have the data and procedures required by current regulations or policies been effective for evaluating impacts or determining mitigation techniques?

8) Do current state or federal regulations or policies restrict any new or innovative procedures that could be implemented to benefit wildlife? (i.e. restricted flexibility for implementing procedures for site-specific problems)

9) Have regulatory agency wildlife policies changed over the years since the inception of SMCRA? If so, how? Are these changes beneficial?

10) Given your existing wildllife budget, how could the money be more effectively used to benefit wildlife with respect to the mining operation?

11) In what areas of impact assessment, mitigation planning, and success determination do you feel that future research is needed?

ISSUES:

AGENCY INTERVIEW FORM

Agency_________________________________ Date____________________________

Contact________________________________ Phone___________________________

Location_______________________________ Interviewer_____________________

1) Are wildlife guidelines or written policies available for permitting coal mines?

2) If not, how are wildlife requirements formulated for baseline studies, impact assessment, and mitigation planning?

3) By species group, what general data collection procedures are recommended or acceptable? Also, what types (qualitative, quantitative, existing) of data are required, and what season, or duration, of collection is required?

Big Game

Furbearers

Small Mammals

Raptors

Waterbirds

Upland Gamebirds

Songbirds and Others

Herpetofauna

T & E or State Sensitive Species

4) Are operator collected wildlife data compiled or available in any format other than permit applications (e.g., computer data base, mapping, etc.)? If so, please list.

5) Are wildlife data used by any groups other than state and federal regulatory agencies? If so, who are they, and how are they using the data?

Public or private research groups?

Other operators?

Other agencies?

6) Any research or data collection by operators(s) beyond requirements? If so, what is being done, and at which mines?

7) How have the State wildlife requirements evolved since the inception of SMCRA (e.g., are certain data still collected but no longer required)?

8) Are any currently required data not used for impact assessment? If so, why is this data important?

9) Where do you require more than site-specific (i.e. regional) data?

10) What methods or models are used for assessment of impacts for the species groups identified in Question 3?

site-specific?

cumulative or regional?

applicability of methods?

limitations of methods?

11) What mitigation techniques are employed to attenuate impacts for the species groups listed in Question 3?

site-specific

cumulative

12) Where you chose mitigation techniques for operators, what were these choices based on, and where is emphasis placed?

13) How is the effectiveness of applied mitigation techniques determined?

14) What success standards must be met by applied mitigation?

15) Do you know of any new or innovative wildlife impact assessment or mitigation procedures that are available? If so, what are they?

16) Where are existing impact assessment, mitigation, and success determination procedures inadequate? And, where do you see the need for future research to alleviate these inadequacies?

17) What is the effect of pre- and post-mining land use on your requirements for data collection, impact assessment, and mitigation or monitoring procedures? Where non-wildlife land uses are in conflict with wildlife land uses, how are these conflicts resolved.

18) Any recommendations for case studies in your state? (Please provide your reasons for choices.)

CASE STUDY FACT SHEET

Mine Name______________________________ Date______________________________

Prime Contact__________________________ Phone____________________________

Location_______________________________ Interviewer______________________

Mining Technology____

Mode of Coal Transportation____

1) Pre-mining habitats and land uses?

2) Post-mining habitats and land uses?

3) How was post-mining land use determined and by whom?

4) Specific identified wildlife concerns or problems?

5) Pre-mining studies and data collection?
   Studies implemented

   Types of data collected

   Duration of collection

   Collectors of data

6) How were impacts assessed and how were baseline data used in these assessments?

7) Was data collected but not used for impact assessment or mitigation planning? If so, which and why?

8) Which specific mitigation techniques were implemented?

9) Which monitoring methods were implemented to determine extent of impacts or evaluate mitigation success?

10) Were techniques available to determine extent of impacts or evaluate mitigation success?

11) Were standards or other means available to evaluate mitigation?

12) Did anticipated impacts occur? With expected severity and duration?

13) Has sufficient time passsed to determine extent of impacts or evaluate mitigation success? If not, how much time will be needed?

ISSUES:

APPENDIX B

State Coal Mining Wildlife Regulations

APPENDIX B

NORTH DAKOTA

Regulation 69-05.2-08-15. Permit applications - Permit area - Fish and wildlife resources.

1. Each permit application shall contain a description of the fish and wildlife resources and their habitats on the proposed permit area and on adjacent areas where effects on such resources may reasonably be expected to occur. The description shall be based upon inventories of fish and wildlife and their habitats on the permit area and adjacent areas. The habitats shall be delineated on 1:4,800 scale aerial photographs.

2. The permit applicant shall determine the scope of work, level of detail and timetable for completion of fish and wildlife inventories in consultation with the commission and the state game and fish department and shall submit for approval by the commission a study plan by which fish and wildlife information will be acquired.

Regulation 69-05.2-09-17. Permit applications - Operation and reclamation plans - Fish and wildlife resources.

1. Each permit application shall contain a fish and wildlife management plan for the proposed permit area and adjacent areas where impacts could reasonably be expected to occur. The plan shall contain a description of the mining and reclamation procedures to be used to comply with section 69-05.2-13-08.

2. Each permit application shall contain a fish and wildlife monitoring plan whereby selected indicator species of fish and wildlife are monitored to assess the effects of surface mining on fish and wildlife resources. Species to be monitored shall be selected by the permit applicant in consultation with the commission and the state game and fish department.

3. Results from implementing the fish and wildlife management plan and data derived from the fish and wildlife monitoring plan for the calendar year shall be reported to the commission by February fifteenth every year.

Regulation 69-05.2-13-08. Performance standards - General requirements - Protection of fish, wildlife, and related environmental values.

1. The permittee shall affirmatively demonstrate how protection and enhancement of fish and wildlife resources will be achieved where practicable on the basis of information gathered and management plans developed in accordance with sections 69-05.2-08-15 and 69-05.2-09-17.

2. The permittee shall promptly report to the commission the presence in the permit area of any critical habitat of a threatened or endangered species, any plant or animal listed as threatened or endangered, or any bald or golden eagle, of which that permittee becomes aware and which was not previously reported to the commission.

3. The permittee shall ensure that the design and construction of electric powerlines and other transmission facilities used for or incidental to the surface mining activities on the permit area are in accordance with the guidelines set forth in Environmental Criteria for Electric Transmission Systems (U.S. Department of the Interior, U.S. Department of Agriculture (1970)), or in alternative guidance manuals approved by the commission. Distribution lines shall be designed and constructed in accordance with REA bulletin 61-10, Powerline Contacts by Eagles and Other Large Birds, or in alternative guidance manuals approved by the commission.

4. The permittee shall, to the extent possible using the best technology currently available:

    a. Locate and operate haul and access roads, sedimentation ponds, diversions, stockpiles and other such structures so as to avoid or minimize impacts to important fish and wildlife species and their habitats and to other species protected by state or federal law.

    b. Create no new barrier in known and important wildlife migration routes.

    c. Fence, cover, or use other appropriate methods to exclude wildlife from ponds which contain hazardous concentrations of toxic-forming materials.

    d. Reclaim, enhance where practicable or avoid disturbance to habitats of unusually high value for fish and wildlife.

    e. Reclaim, enhance where practicable, or maintain natural riparian vegetation on the banks of streams, lakes, and other wetland areas.

    f. Afford protection to aquatic communities by avoiding stream channels as required in section 69-05.2-16-20 or reclaiming stream channels as required in section 69-05.2-16-07.

    g. Not use pesticides in the area during surface mining and reclamation activities, unless specified in the operation and reclamation plan or approved by the commission on a case-by-case basis.

    h. To the extent possible prevent, control and suppress range, forest, and coal fires which are not approved by the commission as part of a management plan.

i. If fish and wildlife habitat is to be a primary or secondary postmining land use, the operator shall in addition to the requirements of chapter 69-05.2-22:

    (1) Select plant species to be used on reclaimed areas, based on the following criteria:

        (a) Their proven nutritional value for fish and wildlife.

        (b) Their uses as cover for fish and wildlife.

        (c) Their ability to support and enhance fish and wildlife habitat after release of bonds.

    (2) Distribute plant groupings to maximize benefits to fish and wildlife. Plants should be grouped and distributed in a manner which optimizes edge effect, cover, and other benefits for fish and wildlife.

j. Where cropland is to be the alternative postmining land use on lands diverted from a fish and wildlife premining land use and where appropriate for wildlife and crop management practices, intersperse the fields with trees, hedges, or fence rows throughout the harvested area to break up large blocks of monoculture and to diversify habitat types for birds and other animals. Wetlands shall be preserved when feasible or recreated consistent with the reclamation plan and the postmining land use.

k. Where the primary land use is to be residential, public service, or industrial land use, intersperse reclaimed lands with greenbelts utilizing species of grass, shrubs, and trees useful as food and cover for birds and small animals, unless such greenbelts are inconsistent with the approved postmining land use.

MONTANA

Regulation 26.4.304 INFORMATION ON ENVIRONMENTAL RESOURCES

(12) a wildlife survey, which shall include:

(a) a listing of the fish and wildlife (including, but not limited to birds, mammal, fishes, reptiles, and amphibians) species utilizing the permit area, including any species on the rare and endangered list prepared by the U.S. Bureau of Sports Fisheries and Wildlife (threatened wildlife of the United States);

(b) population density estimates of each species insofar as practicable;

(c) season or seasons of use by each species must be noted along with a discussion of winter concentration areas, fawning or calving areas, nesting or brooding areas and spawning areas in the area affected;

(d) an aerial reconnaisance photographic survey of the area to be affected, if required by the department;

(e) the wildlife survey shall include an area 2 miles in all directions from the permit area. The survey shall only include the proposed mine plan area for species whose home ranges do not extend beyond the proposed mine plan area. The department may modify the 2 mile requirements if the applicant cannot gain access to portions of the 2 mile area. However in all cases the information required by (a) through (d) must be furnished. Also included shall be a wildlife habitat map for the entire wildlife survey area;

Regulation 26.4.312 FISH AND WILDLIFE PLAN Each application shall contain a fish and wildlife plan, consistent with Rule 26.4.751 which provides:

(1) a statement of how the plan will minimize disturbances and adverse impacts on fish and wildlife and related environmental values during strip mining operations, and how enhancement of these resources will be achieved, where practicable. The plan shall cover the mine plan area and portions of adjacent areas as determined by the department pursuant to Rule 26.4.304(12), nothing herein shall be construed to weaken the requirement of section 82-4-233(1)(a);

(2) if the applicant states that it will not be practicable in accordance with paragraph (1) above, to achieve a condition which clearly shows a trend toward enhancement of fish and wildlife resources at the time revegetation has been successfully completed, a statement shall be provided which establishes, to the satisfaction of the department, why it is not practicable to achieve such a condition. (History: Sec. 82-4-204, 205 MCA; IMP, Sec. 82-4-222; NEW, 1980 MAR p. 725, Eff. 4/1/80.)

Regulation 26.4.751 PROTECTION OF FISH, WILDLIFE, AND RELATED ENVIRONMENTAL VALUES In addition to the requirements of section 82-4-231(3)(j), an operator shall:

(1) promptly report to the department the presence in the permit area of any critical habitat of a threatened or endangered species listed by the Secretary of the Interior, any plant or animal listed as threatened or endangered by Montana, or any bald or golden eagle, of which that person becomes aware and which was not previously reported to the department by that person;

(2) ensure that the design and construction of electric power lines and other transmission facilities used for or incidental to the strip or underground mining operations on the permit area are in accordance with the guidelines set forth in environmental criteria for electric transmission system (USDI, USDA (1970), or in alternative guidance manuals approved by the department. Distribution lines shall be designed and constructed in accordance with REA Bulletin 61-10, powerline contacts by eagles and other large birds, or in alternative guidance manuals approved by the department. For information purposes, these two documents are on file at the Helena office of the department;

(3) locate and operate haul and access roads so as to avoid or minimize impacts to important fish and wildlife species or other species protected by state or federal law;

(4) fence roadways where specified by the department to guide locally important wildlife to roadway underpasses. No barrier shall be created in known and important wildlife migration routes;

(5) fence, cover, or use other appropriate methods to exclude wildlife from ponds which contain hazardous concentrations of toxic-forming materials;

(6) ensure that reclamation will provide for habitat needs of various wildlife species in an equal or greater capacity than was provided prior to mining; special attention should be given to inanimate elements such as rock outcrops, boulders, scoria rubble, dead trees, etc., which may have existed on the surface prior to mining; such elements should be recreated on post-mined areas to provide comparable habitat needs for wildlife;

(7) restore, consistent with 82-4-233, or avoid disturbance to habitats of unusually high value for fish and wildlife, and, where practicable, enhance such habitats;

(8) restore, consistent with 82-4-233, or maintain natural riparian vegetation on the banks of streams, lakes, and other wetland areas and, where practicable, enhance such habitats;

(9) afford protection to aquatic communities by avoiding stream channels or restoring stream channels as required in Rule 26.4.634;

(10) not use pesticides on the area during strip or underground mining and reclamation operations unless approved by the department; and

(11) to the extent possible prevent, control, and suppress range, forest, and coal fires which are not approved by the department as part of a management plan. (History: 82-4-204, 205 MCA; IMP, Sec. 82-4-227, 231 MCA; NEW, 1980 MAR p. 725, Eff. 4/1/80.)

WYOMING

Chapter 2: Section 2. General application content requirements.

(e) Indigenous wildlife

(i) The operator shall submit a list of the indigenous vertebrate wildlife species by common and scientific names observed within one (1) mile of the proposed permit area.

(ii) Special attention shall be paid to the possible presence of wildlife on or adjacent to the proposed permit area which are listed on the "Endangered Species List", of the Wyoming Game and Fish Department.

(iii) If significant habitat or migration route disruption is possible or likely, the Wyoming Game and Fish Department shall be contacted in order to determine the types and numbers of wildlife likely to be disturbed or displaced.

Chapter 2: Section 3. Special application content requirements for surface coal mining operations.

(e) Studies of fish, wildlife, and their habitats, in the level of detail and for those areas as determined by the administrator, after consultation with the Wyoming Game and Fish Department in accordance with the memorandum of understanding between the two agencies; and federal agencies having responsibilities for the management or conservation of such environmental values;

(4) A plan for minimizing adverse impacts to fish, wildlife and related environmental values within and adjacent to the permit area during the operation, including:

(a) Whether such resources will be enhanced through successful revegetation in accordance with Chapter IV, Section 3.p.;

(b) A statement of how the applicant will utilize impact control measures, management techniques, and monitoring methods to protect or enhance the following, if they are to be affected by the proposed operation:

(i) Threatened or endangered species of plants or animals listed by the Secretary under the Endangered Species Act of 1973, as amended (16 U.S.C. Section 1531 et seq.) and their critical habitats;

(ii) Species identified through the consultation process described in a.(6)(e) of this section;

(iii) Habitats of unusually high value for fish and wildlife, such as wetlands, riparian areas, rimrocks, areas offering special shelter or protection, reproduction and nursery areas, and wintering areas.

Chapter 4: Section 3. Special environmental protection performance standards applicable to surface coal mining and reclamation operations.

k. All support buildings, including loading and storage facilities, plants, sheds, shops and other buildings shall be designed, constructed or reconstructed and located to prevent or control erosion, pollution, and damage to public or private property, fish, wildlife, and related environmental values. All operations shall be conducted so as minimize disruption of any services provided by facilities located on, under or through the permit area, unless otherwise approved by the administrator or owner of such facilities.

p. Fish and wildlife performance standards.

(1) An operator shall, to the extent possible using the best technology currently available and consistent with the approved postmining land use, minimize disturbance and adverse impacts on fish, wildlife, and related environmental values, and achieve enhancement of such resources where practicable, which activities shall include:

(a) Properly construct, locate and operate roads and powerlines, including proper design of powerlines to avoid electrocution of raptors,

(b) Fence or otherwise control areas, such as roadways or ponds with hazardous materials, to control wildlife migration, without limiting access to known important routes.

(c) Afford protection, restore and enhance where practicable habitats of high value to fish and wildlife.

(d) Not use persistent pesticides on the permit area unless approved by the administrator;

(e) To the extent possible prevent, control, and suppress range, forest and coal fires which are not approved as part of the management plan.

(f) Select plant species with shrubs well represented, which will enhance the nutritional and cover aspects of fish and wildlife habitat, where such habitat is identified as part of the postmining use, and distribute the reestablished habitat in a manner which includes a diversity and interspersion of habitats, optimizes edge effect, cover and other benefits for fish and wildlife.

(g) Report to the administrator any species or critical habitat of such species listed as threatened or endangered, or any golden eagle, which was not reported or investigated in the permit application.

Chapter 2: Section 2.b.(3)(c)

A plan to assure revegetation of all affected land in accordance with Chapter IV, Section 2.d., and, if applicable, Section 3.d. The plan shall include the method and schedule of revegetation, including but not limited to species of plants, seeding rates, seeding techniques, mulching requirements, and seeding times to be used in a given area for reclamation purposes. The standards and specifications adopted by the State Conservation Commission for mine reclamation shall be considered by the applicant during the preparation of the reclamation plan. Whenever practicable, the Wyoming Game and Fish Department and The Wyoming Department of Agriculture should be consulted regarding revegetation procedures.

Chapter 2: Section 3.a.(12)(b)(iii)(H)

Approval of measures to prevent or mitigate adverse effects on wildlife or fish have been obtained from appropriate state and federal fish and wildlife management agencies:

Chapter 4: Section 2.a.(2)

Operators are required to restore wildife habitat, whenever the administrator determines that this restoration is possible, on affected land in a manner commensurate with or superior to habitat conditions which existed before the land became affected, unless the land is private and the proposed use is for a residential or agricultural purpose which may preclude its use as wildlife habitat.

Chapter 4: Section 3.d.(6)(a)

When wildlife is part of the postmining land use, shrubs and trees shall be returned to a density at least equal to that existing on the area before mining.

COLORADO

Regulation 2.04.11 Fish and Wildlife Resources Information

(1) Each application shall include a study of fish and wildlife and their habitats within the proposed permit area and portions of the adjacent area as determined by the Division, or in the case of underground mining, only those areas within the proposed permit area and portions of the adjacent area as determined by the Division where surface mining will be conducted or facilities located and the portions of the permit area where effects on such resources may reasonably be expected to occur.

(2) Prior to initiating such studies, the applicant shall contact the Division to determine what fish and wildlife resources information will be required.

(3) The Division, in consultation with the appropriate State and Federal fish and wildlife management, conservation, or land management agencies having responsibilities for fish and wildlife or their habitats, shall determine the level of detail and the areas of such studies, according to:

(a) Published data and other information;

(b) Site-specific information obtained by the applicant; and

(c) Written guidance obtained from agencies consulted.

(4) The potential for impacts to rare and endangered animal species shall be evaluated by the Division in consultation with appropriate Federal and State agencies.

Regulation 2.05.6 Mitigation of Surface Coal Mining Operation Impacts

(2) Fish and Wildlife Plan

(a) Each application shall contain a fish and wildlife plan, consistent with 4.18 which provides:

(i) A statement of how the plan will minimize disturbances and adverse impacts on fish and wildlife and related environmental values during surface coal mining and reclamation operations, and how enhancement of these resources will be achieved, where practicable. The plan shall cover the permit area and portions of adjacent areas as determined by the Division pursuant to 2.04.11.

(ii) If the applicant states that it will not be practicable, in accordance with 2.05.6(2)(a)(i), to achieve a condition which clearly shows a trend toward enhancement of fish and wildlife resources at the time revegetation has been successfully completed under 4.156, a statement shall be provided which establishes, to the satisfaction of the Division, why it is not practicable to achieve such a condition; and

(iii) A statement explaining how the applicant will utilize impact control measures, management techniques, and monitoring methods to protect or enhance the following, if they are to be affected by the proposed activities:

(A) Threatened or endangered species of plants or animals listed by the Secretary under the Endangered Species Act of 1973, as amended (16 U.S.C. Sec. 1531 et seq.) or the Nongame, Endangered or Threatened Species Conservation Act (Section 33-8-101 et seq., C.R.S. 1973), and their habitats;

(B) Species such as eagles, migratory birds or other animals protected by State or Federal law, and their habitats; or other species identified through the consultation process pursuant to 4.18; or

(C) Habitats of unusually high value for fish and wildlife, such as wetlands, riparian areas, cliffs supporting raptors, areas offering special shelter or protection, reproduction and nursery areas, and wintering areas.

(b) For surface coal mining activities the plan shall include a map, prepared to the standards of 2.10 which shall show the location of each facility to be used to protect and enhance fish and wildlife and related environmental values.

Regulation 4.18 PROTECTION OF FISH, WILDLIFE, AND RELATED ENVIRONMENTAL VALUES

(1) Any person conducting surface coal mining operations shall, to the extent possible using the best technology currently available, minimize disturbances and adverse impacts of the operations on fish, wildlife, and related environmental values, and, where practicable, achieve enhancement of such resources.

(2) A person who conducts surface coal mining operations shall promptly report to the Division the presence in the permit area of:

(a) Any threatened or endangered animal or plant species listed or proposed to be listed by the State or Secretary;

(b) Any critical habitat of any threatened or endangered animal or plant species listed or proposed to be listed by the State or Secretary; or

(c) Any bald or golden eagle, or nest thereof, of which that person becomes aware and which was not previously reported to the Division by that person.

(3) A person who conducts surface coal mining operations shall ensure that the design and construction of electric power lines and other transmission facilities used for or incidental to the surface coal mining operations, on the permit area are in accordance with the guidelines set forth in the Environmental Criteria for Electric Transmission System (USDI, USDA (1970)), or in alternative guidance manuals approved by the Division. Distribution lines shall be designed and constructed in accordance with REA Bulletin 61-10, Powerline Contacts by Eagles and Other Large Birds, or in

alternative guidance manuals approved by the Division. For information purposes, these two documents are available for inspection at the office of the Division.

(4) Each person who conducts surface coal mining operations, to the extent possible using the best technology currently available, shall:

(a) Locate and operate roads so as to avoid or minimize impacts to fish and wildlife species;

(b) Fence roadways where specified by the Division to guide locally important wildlife to roadway underpasses. No new barrier shall be created in known and important wildlife migration routes as identified by the State;

(c) Fence, cover, or use other appropriate methods to exclude wildlife from ponds which contain hazardous concentrations of toxic-forming materials;

(d) Restore, enhance where practicable, or avoid disturbance to habitats of unusually high value for fish and wildlife as identified by the State;

(e) Restore, enhance where practicable, or maintain natural riparian vegetation on the banks of streams, lakes and other wetland areas;

(f) Afford protection to aquatic communities by providing stream channel buffer zones as required in 4.05.18 and 4.20.4 or restoring stream channels as required in 4.05.4;

(g) Not use persistent pesticides on the area during surface mining and reclamation operations, unless approved by the Division;

(h) To the extent possible, prevent, control, and suppress range, forest and coal fires which are not approved by the Division as part of a management plan;

(i) If fish and wildlife habitat is to be a primary or secondary postmining land use, the operator shall, in addition to the requirements of 4.15:

(i) Select plant species to be used on reclaimed areas, based on the following criteria:

(A) Their proven nutritional value for fish and wildlife,

(B) Their uses as cover for fish and wildlife, and

(C) Their ability to support and enhance fish and wildlife habitat after release of bonds; and

(ii) Distribute plant groupings to maximize benefit to fish and wildlife. Plants should be grouped and distributed in a manner which optimizes edge effect, cover, and other benefits for fish and wildlife;

(j) Where cropland is to be the alternative postmining land use on lands diverted from a fish and wildlife premining land use, and where appropriate for wildlife and crop management practices, intersperse the fields with crops, hedges, fence rows or areas of natural vegetation throughout the cultivated area to break up large blocks of monoculture or to diversify habitat types for birds and other animals. Wetlands shall be preserved or created rather than drained or otherwise permanently abolished; and

(k) Where the primary land use is to be residential, public service, or industrial land use, intersperse reclaimed lands with greenbelts utilizing species of grass, shrubs and trees useful as food and cover for birds and small animals, unless such green belts are inconsistent with the approved postmining land use.

Regulation 8-19 Vegetation information (779.19 and 783.19)

(d) The map or aerial photograph required shall include sufficient adjacent areas to allow evaluation of vegetation as important habitat for fish and wildlife for those species of fish and wildlife identified under Section 8-20. The map may be prepared by the local Soil and Water Conservation District of the area or other qualified government or private organization.

Regulation 8-20 Fish and wildlife resources information (779.20 and 783.20)

(a) If required by the Director, each application shall include a study of fish and wildlife and their habitats within the proposed permit area and the portions of the adjacent areas where effects on such resources may reasonably be expected to occur.

(b) The applicant in consultation with the appropriate State fish and wildlife management, conservation, or land management agencies having responsibilities for fish and wildlife or their habitats, shall propose the level of detail and the areas of such studies, after consideration of available:

(1) Published data and other information;

(2) Site-specific information obtained by the applicant; and

(3) Guidance obtained from agencies consulted.

(c) The Director in consultation with the appropriate agencies will approve or disapprove that level of detail in the study.

Regulation 9-16 Fish and wildlife plan (780.16 and 784.21)

(a) If required by the Director, each application shall contain a fish and wildlife plan, consistent with Section 20-97 which provides:

(1) A statement of how the plan will minimize disturbances and adverse impacts on fish and wildlife and related environmental values during surface coal mining and reclamation operations, and how enhancement of these resources will be achieved, where practicable. The plan shall cover the permit and adjacent areas as determined by the Director pursuant to Section 8-20(c).

(2) If the applicant states that it will not be practicable, in accordance with paragraph (1), to achieve a condition which clearly shows a trend toward enhancement of fish and wildlife resources at the time revegetation has been successfully completed under Sections 20-111 through 20-117, a statement explaining why it is not practicable to achieve such a condition shall be submitted to the Director.

(b) A statement describing the method, if any, the applicant will utilize to protect or enhance the following, if they are to be affected by surface coal mining operations:

> (1) Threatened or endangered species of plants or animals which are indigenous to the State listed under the Endangered Species Act of 1973 as amended, and the Wildlife Conservation Act, Sections 17-6-1 *et seq.* NMSA 1978, the Habitat Protection Act, Sections 17-6-1 *et seq.* NMSA 1978, and the laws relating to the protection of native New Mexico plants including Sections 76-8-1 through 76-8-4 NMSA 1978; and their critical habitats;
>
> (2) Species such as eagles, migratory birds or other animals protected by State or Federal Law, and their habitats; or other species identified through the consultation process pursuant to Section 8-20; or
>
> (3) Habitats of unusually high value for fish and wildlife, such as wetlands, riparian areas, cliffs supporting raptors, areas offering special shelter or protection, reproduction and nursery areas, and wintering areas.

Regulation 20-97 Protection of fish, wildlife, and related environmental values (816.97 and 817.97)

(a) Any person conducting surface coal mining operations shall, to the extent possible using the best technology currently available, minimize disturbances and adverse impacts of the operations on fish, wildlife, and related environmental values, and achieve enhancement of such resources where practicable.

(b) A person who conducts surface coal mining operations shall promptly report to the Director the presence in the permit area of any critical habitat of a threatened or endangered species listed by the Secretary of the U.S. Department of Interior, any plant or animal listed as threatened or endangered by the State, or any bald or golden eagle, of which that person becomes aware and which was not previously reported to the Director by that person.

(c) A person who conducts surface coal mining operations shall ensure that the design and construction of electric power lines and other transmission facilities used for or incidental to the surface coal mining operations on the permit areas are in accordance with the guidelines set forth in Environmental Criteria for Electric Transmission System (USDI, USDA (1970)), or in alternative guidance manuals approved by the Director. Distribution lines shall be designed and constructed in accordance with REA Bulletin 61-10, Powerline Contacts by Eagles and Other Large Birds, or in alternative guidance manuals approved by the Director.

(d) Each person who conducts surface coal mining operations shall, to the extent possible using the best technology currently available -

> (1) Locate and operate haul and access roads so as to avoid or minimize impacts to important fish and wildlife species or other species protected by State or Federal law;

(2) Fence roadways where specified by the Director to guide locally important wildlife to roadway underpasses or overpasses. Construction of other necessary passageways may be required by the Director. No new barrier shall be created in known and important wildlife migration routes;

(3) Fence, cover, or use other appropriate methods to exclude wildlife from ponds which contain hazardous concentrations of toxic-forming materials;

(4) Restore, enhance where practicable or avoid disturbance to habitats of unusually high value for fish and wildlife;

(5) Restore, enhance where practicable, or maintain natural riparian vegetation on the banks of streams, lakes, and other wetland areas;

(6) Afford protection to aquatic communities by avoiding stream channels as required in Sections 20-57 and 20-126 or restoring stream channels as required in Section 20-44.

(7) Not use persistent pesticides on the area during surface coal mining and reclamation operations, unless approved by the Director.

(8) To the extent possible prevent, control, and suppress range, forest, and coal fires which are not approved by the Director as part of a management plan.

(9) If fish and Wildlife habitat is to be a primary or secondary postmining land use, the operator shall in addition to the requirements of Sections 20-111 through 20-117 of these regulations -

(i) Select plant species to be used on reclaimed areas, based on the following criteria -

(A) Their proven nutritional value for fish and wildlife;

(B) Their uses as cover for fish and wildlife; and

(C) Their ability to support and enhance fish and wildlife habitat after release of bonds; and

(ii) Distribute plant grouping to maximize benefit to fish and wildlife. Plants should be grouped and distributed in a manner which optimizes edge effect, cover, and other benefits for fish and wildlife.

(10) Where cropland is to be the alternative postmining land use on lands diverted from a fish and wildlife premining land use and where appropriate for wildlife and crop management practices, intersperse the fields with trees, hedges or fence rows throughout the harvested area to break up large blocks of monoculture and to diversify habitat types for birds and other animals. Wetlands shall be preserved or created rather than drained or otherwise permanently abolished; and

(11) Where the primary land use is to be residential, public service, or industrial land use, intersperse reclaimed lands with greenbelts utilizing species of grass, shrubs and trees useful as food and cover for birds and small animals, unless such greenbelts are inconsistent with the approved postmining land use.

APPENDIX C

State Wildlife Guidelines

APPENDIX C

Reclamation Division
Department of State Lands
Helena, Montana 59601

WILDLIFE SURVEY GUIDELINES

These guidelines should be used as a basis to set up the wildlife survey on areas to be mined for coal. The wildlife survey should be considered as a study of the overall ecology of the area.

Important species or key species to be studied cannot be named beforehand. Any organism may be important or critical in various areas. Although game animals are important and convenient species to study as techniques are well known for most game species, the study should also identify non-game species, and consider the total ecology of the area to determine important species and/or habitats within the study area.

The law directs the department to approve applications assuming no jeopardy to species of wildlife or domestic stock. As wildlife is not limited to game species, the permanent loss of productivity of any species is grounds for denial of a permit. Pragmatically this concept places a great importance and dependence on the success of reclamation and upon the ability to identify habitats critical to organisms in and around the area to be mined.

The duration of the study will be in two phases with first a wildlife and wildlife habitat inventory before any disturbance. The second, monitoring the on-going operation to analyze the success of reclamation and to monitor various indices for trend comparisons.

The law calls for seasons of use by each species which basically means a minimum of one year premining inventory, taking into consideration climatic conditions which may limit or expand the use of certain species on the area any particular year. A preferable study design would include two (2) winter seasons during the course of the study. The monitoring activity shall be carried out until mining in the area is completed and reclamation is considered complete.

The scope of work as defined by field time should follow these guidelines for minimum field work:

Pre-mining inventory

field time = 1 year on the site, a biologist working on the site for 1 year considering a 5 day work week

aerial coverage = 2 times/month for 1 year

APPENDIX C

Reclamation Division
Department of State Lands
Helena, Montana 59601

WILDLIFE SURVEY GUIDELINES

These guidelines should be used as a basis to set up the wildlife survey on areas to be mined for coal. The wildlife survey should be considered as a study of the overall ecology of the area.

Important species or key species to be studied cannot be named beforehand. Any organism may be important or critical in various areas. Although game animals are important and convenient species to study as techniques are well known for most game species, the study should also identify non-game species, and consider the total ecology of the area to determine important species and/or habitats within the study area.

The law directs the department to approve applications assuming no jeopardy to species of wildlife or domestic stock. As wildlife is not limited to game species, the permanent loss of productivity of any species is grounds for denial of a permit. Pragmatically this concept places a great importance and dependence on the success of reclamation and upon the ability to identify habitats critical to organisms in and around the area to be mined.

The duration of the study will be in two phases with first a wildlife and wildlife habitat inventory before any disturbance. The second, monitoring the on-going operation to analyze the success of reclamation and to monitor various indices for trend comparisons.

The law calls for seasons of use by each species which basically means a minimum of one year premining inventory, taking into consideration climatic conditions which may limit or expand the use of certain species on the area any particular year. A preferable study design would include two (2) winter seasons during the course of the study. The monitoring activity shall be carried out until mining in the area is completed and reclamation is considered complete.

The scope of work as defined by field time should follow these guidelines for minimum field work:

Pre-mining inventory

field time = 1 year on the site, a biologist working on the site for 1 year considering a 5 day work week

aerial coverage = 2 times/month for 1 year

Monitoring activity

field time = 100 man days/year (not consecutive)

aerial coverage = 1/month

The above time frame is that required for large operations in areas that have not been studied previously by other researchers.

Major Objectives Of The Survey

I) To obtain a list of fish and wildlife species using the area. Wildlife is not limited to game species. Special attention must be given to the possibility of rare and endangered species utilizing the area.

II) To obtain relative population density estimates of major wildlife and ecologically important species. The importance of any particular species will be based upon the presence of critical habitats.

III) To assess different habitat types within the area, to delineate wildlife use of these types and to determine the degree of wildlife dependence on these types. Standardization of habitat typing within our region should be attempted. Vegetation work should be conducted to properly evaluate where to place transects or trap lines.

IV) To show season or seasons of use of an area, by each species present.

V) To monitor the area and comparable control areas on a continuing basis compiling trend data for analysis. The monitoring phase of the study will be reduced in the scope of field time, as noted previously, except in case of continued expansion or multiple mine activity.

Basic objectives of the monitoring activity will be as follows:

A) Collect trend information utilizing indices used in the premining inventory. Monitoring over the long term will answer questions of adequacy of restoration of wildlife habitat in relative terms.

B) Analyze the effects of mining disturbance upon the ecology of the area.

1) Determine displacement effect around the mine area and any migration into or away from mining areas by certain species.

2) Determine effectiveness of reclaimed areas in terms of support and maintenance compared to native biological productivity.

3) Add to the list of species utilizing the mining area as climatic and other changes result in additional "seasons of use" data.

Method Of Wildlife Survey

The following techniques are being used to fulfill the objectives outlined previously. All techniques are subject to modification to fit the requirements of specific situations. It is also inherent in any study design that allowances for expanded research be made in case unforseen problems arise.

1) After receipt of the law, rules and regulations and guidelines, the researcher shall present a study proposal to the Reclamation Division for review.
2) After evaluation of the proposal and field inspection, meetings will be set to discuss and modify the proposal. At the conclusion the plan will be approved by the Reclamation Division.
3) During the survey close contact must be maintained with the Reclamation Division to assure that misunderstandings and unforeseen problems are cleared up.

Standard techniques are as follows:

(1) Literature research of all available, and applicable wildlife information concerning the organisms in the study area.

(2) Communications with local residents, Fish & Game personnel, or any knowledgeable parties.

(3) Direct observations of wildlife is a basic component of the survey. Observation routes should be set up to cover the whole area. Location and frequency of use of these routes must be tabulated and approved observation sheets utilized. Observations should be made utilizing coordinated system to locate each observation in the study area. Detailed field notes are necessary. Information such as: date; time of day; climatic conditions; condition and sex of the organism; activity of the organism; flight, feeding, etc.; habitat type being utilized are examples of the information that should be tabulated. Maps must be submitted showing routes to be used for ground and aerial runs.

Aerial observations surveys should be explained in detail. Information concerning dates of flights, duration of flights, type of plane, route of flights, altitude and speed should be explained.

(4) Small mammal trap should be set up to monitor population trends in different habitat types. The techniques used should be applicable to testing reclaimed areas. Some grids and/or traplines should be in areas which won't be disturbed for comparison purposes. Spring and fall trapping should furnish necessary information.

(5) Crowing counts should be made when applicable. This technique is a standard auditory index census and will furnish pheasant trend information.

(6) Dancing and strutting grounds should be censused at least twice a spring for trend information. In some cases it may be valuable to visit the grounds in the fall also. In cases where these grounds will be disturbed a more intense study utilizing tagging and/or radio tracking to understand size, range, and local habitat needs of the population utilizing the ground will be required.

A breeding bird survey should be conducted to furnish information for the species list, territory, habitat use by certain species, etc.

Special attention should be paid to nesting raptors and colonial nesting birds. Disturbance of nesting birds should be kept to a minimum until more intensive studies are started.

(7) The use of the various habitats in and around the area for food, cover, escape routes; etc. should be noted and discussed. Utilization of various habitats or vegetation types for food sources should be documented by browse transects, time observation of feeding animals, scat examination and stomach or crop examination of road killed or hunter killed animals.

(8) A complete inventory of aquatic vertebrates and invertebrates in waters receiving surface or groundwater from the mine area should be made. Aquatic plants, both macrophytes and algae (including diatoms), also should be inventoried and monitored. Aquatic biological studies should follow one of the listed references:

1. American Public Health Association. 1971. Standard Methods for the Examination of Water and Wastewater. Thirteenth Edition, A.P.H.A., Washington, D.C.

2. Environmental Protection Agency. 1973. Biological Field and and Laboratory Methods for Measuring the Quality of Surface Waters and Effluents. National Environmental Research Center, Cincinnati, Ohio.

Water quality data will be required for such streams and bodies of water on a periodic basis. More detailed analysis of the above items will be required on a site by site basis depending upon the nature of potential aquatic impacts.

The above guidelines outline the objectives which must be adhered to and outlines some basic techniques for wildlife surveys to be conducted. In the planning stages of the study detailed descriptions of each study technique must be submitted to the Reclamation

Division biologist for review. Information concerning field time and intervals of field time must be clearly defined before approval is given. The planning phase should incorporate valid statistical testing into the study design. Data should be analyzed for statistical significance.

There are many different techniques which may be employed to adequately study the ecology of the area. All techniques must be outlined in detail to the Reclamation Division biologist before study approval is given. Any changes in the study design should be brought to the attention of the Reclamation Division biologist for concurrence before implementation.

WYOMING DEPARTMENT OF ENVIRONMENTAL QUALITY
LAND QUALITY DIVISION
GUIDELINE NO. 5

DRAFT

WILDLIFE

This document is a guideline only. Its contents are not to be interpreted by applicants or DEQ staff as mandatory. The guideline is intended to assist mine permit applicants in conducting wildlife inventories and in preparing wildlife sections of mining and reclamation plans. The term "Wildlife", as used here, means both terrestrial and aquatic species. Suggested methods are designed to standardize data reported in permit applications, yet allow flexibility in choosing survey methods. Alternate methods are acceptable if they yield comparable results. To avoid disagreements during the permit review process, however, we encourage that alternate methods be cleared with the Game and Fish Department or DEQ prior to their implementation. Data should be presented as outlined in the attached appendix. The general recommendations of this guideline are designed for the larger surface mining operations. Depending on the size, location, and specific impacts of an operation, certain portions of this guideline may not apply. Permit applicants should consult the Wyoming Game and Fish Department or the Department of Environmental Quality to develop baseline study designs appropriate for individual operations. In some cases, baseline information may be available from studies conducted in similar habitat types on adjacent surfaces. If this information is current (collected within 5 years preceding the application submittal) it may be referenced in lieu of collecting new data. The requested information will allow determination of:

1. Composition of the wildlife community, species diversity, and habitat affinity prior to mining.
2. Mining impacts upon wildlife and habitat.
3. Effectiveness of mitigation and reclamation proposals.

I. Information needed in a wildlife inventory

A. A Description of the vertebrate fauna of the area

(1) Potential
A list should be developed to indicate species likely to occur in the area according to literature sources such as those at the end of this guideline. The list should be compiled before undertaking field studies, but after a visit to the site. Common sense should be used in preparing the list. If habitat for a particular species is not present, the species should not be listed, even though its range overlaps the mine site. The potential species list should appear as a table in appendix D-9 of the permit application.

(2) Actual

This includes species recorded on the permit area based upon observations of animals or their sign during trapping or census activities, existing data for the area, and reliable reports from local observers such as state, federal, and company biologists and local ranchers. These can be indicated on the potential species list by an asterisk.

(3) Habitat Description

Wildlife habitat on the permit area should be classified according to habitat types used in the Wyoming Game and Fish Department's Wildlife Observation System (see Literature Cited). Both vegetative and physical habitat types should be included. Vegetative types are generally the major plant communities, while physical types include such things as stockponds, playas, rough breaks, rock outcrops, and rimrocks. The acreage encompassed by each habitat type and the acreage to be disturbed should be tabulated for impact analysis. All habitat types existing prior to mining should be delineated on a map except those physical types that occupy little area or are too interspersed within a vegetative type to be mapped.

The purpose of this is to indicate the amount of wildlife habitat and its location on the permit area before mining in order to evaluate the reclamation plan.

(4) Habitat Affinity

Habitat affinity data are designed to illustrate which habitat types are of most value to wildlife. The intent is to use this information to decide whether postmining reclamation is adequate to restore important wildlife habitat. The underlying assumption is that if an animal is present in a habitat type and has not been chased or otherwise forced there, it has an affinity or attraction to that habitat type. Those habitat types for which the most wildlife species have an affinity are presumed to be the most valuable, and those needing emphasis in wildlife-oriented reclamation.

A biologist sampling for habitat affinity is sampling animal occurrence as indicated by presence of the animal or its sign. Observations used to determine habitat affinity cannot be based upon one or two days' data. There should be several observation periods throughout the biological year, since affinity may change seasonally depending upon life function requirements at various times of the year. Habitat affinity determination requires accumulation of data from direct counts, bird transects, brood counts, raptor surveys, small mammal trapping, and incidental observations. The biologist should record the habitat type in which an animal is observed each time an observation is made. The relative value of each habitat can be determined from the number of species seen there and the relative value of certain habitat types to individual species can be based on the frequency of occurrence in each habitat type. To avoid bias due to an unbalanced sampling approach, frequency of occurrence should be adjusted to reflect the amount of sampling effort expended in each habitat type.

For some animals, habitat affinity on-site may be the same yearlong. For example, mule deer on many coal leases may only be found in rough, broken terrain, in riparian habitat, or in stands of scattered trees and tall shrubs. Bushy-tailed woodrats and cottontail rabbits may only occur along a rimrock. There will be a relationship between some wildlife species and certain topographic or vegetative features on all areas surveyed.

B. Seasonal Data Collection

An adequate assessment of wildlife occurrence in an area cannot be made in less than one year. "Seasonal" as used in this guideline does not mean sampling in spring, summer, fall, and winter for all species. The following intervals for data collection reflect periods of "seasonal" importance in the annual cycle of various wildlife groups:

(1) Big Game All Seasons--numbers, distribution and habitat affinity. Particularly important are winter occurrence (January - February). Production prehunt (July - August) and total numbers posthunt (November - December).

(2) Upland Game Birds
Breeding counts (April
Production of young (Mid-June - August)
Winter occurrence (December - Mid-February)
Seasonal habitat affinity

(3) Raptors
Nest location (Yearlong)
Nest status - active or inactive (April)
Production - are young present? (June)
Winter occurrence (December - Mid-February)

(4) Waterfowl and Shorebirds
Spring migration (April - May)
Fall migration (September - November)
Production - are young present? (late June - July)

(5) Passerine Birds
Breeding (late May - June)
Winter occurrence (December - February)
Habitat affinity during each of the above seasons

(6) Other Mammals
Species occurrence - all seasons (by incidental observations of animals and sign)
Small mammals - trapping (July - September)
Rabbits (August - January)
Habitat affinity during each of the above seasons

(7) Threatended and Endangered Species
Peregrine falcon (March - May, September - November)
Black-footed ferret (July 1-September 15, December 1-April 15)

Bald Eagle breeding and nesting (April - Mid-June)
Winter eagle roosts or feeding areas (January - February)
Whooping Crane and Grizzly Bear - where survey is necessary, consult WGFD and USFWS

(8) Reptiles and Amphibians
Breeding and abundance (May - July)
There are species variations and altitudinal variations for both groups.

(9) Fish
Breeding (March - November, with species variations)
Abundance (all year)

C. Data Analysis

All data should be reported on Wyoming Game and Fish Department Wildlife Observation Forms and copies sent to the area biologist. Data should be presented in Appendix D-9 of the mine permit application. At the beginning of the section on each group of animals, data collection techniques should be described in sufficient detail that they could be replicated by a competent field biologist. Otherwise, an appropriate literature citation should be provided. Dates of data collection should be specified. An analysis and thorough discussion of the data should be included by groups of animals (raptors, big game, other mammals, passerine birds, etc). Anticipated impacts on wildlife should be summarized. Big game, upland game, raptor, predator, and rare species sightings should be plotted on the habitat map along with locations of trapping plots, transects, and driving (survey) routes. If necessary, the requested data may be plotted on more than one map to avoid cluttering.

D. Mitigation Plan

Once potential impacts have been assessed by the company, methods to minimize impacts to wildlife during and after mining should be described in the Mine Plan. All fence designs should be provided, referencing specific types described in Guideline 10. Impact abatement procedures will often be tailored to fit individual sites. Acceptable mitigation includes proper fencing, obtaining or providing recreational access, controlled speed limits, programs to educate employees about game laws and sensitive wildlife species, replacement of dead snags, creation or development of water sources, protection of riparian areas from grazing, reestablishment of raptor nesting sites, wildlife-oriented reclamation, problem solving research, and habitat improvement projects. Mine personnel are encouraged to develop new and innovative techniques (within legal constraints) to help offset mine impacts. The U.S. Fish and Wildlife Service, Office of Ecological Services, should be contacted early regarding raptor nest conflicts and the possible presence of threatened or endangered species. The outcome of this consultation should be discussed in the Mine Plan. Mitigation procedures should be described and supported by a letter of concurrence from the USFWS.

E. Reclamation Plan

Where wildlife habitat will be part of the postmine land use, Land Quality Division regulations require development of a plan to restore this use. All habitat reclamation procedures should be described in the Reclamation Plan of the permit application. Unless the premining landscape was badly managed, baseline data on wildlife use of the permit area will provide a valuable reference for development of the reclamation plan and for evaluating the effectiveness of current reclamation practices. For wildlife reclamation, emphasis should be placed upon habitat features that promote maximum species diversity following mining. The reclamation plan should be an integration of vegetative components and those physical (landform) features required to perpetuate diverse plant communities. Reclamation designed to produce shrubland or a mixture of grasses, shrubs, and forbs will benefit wildlife more than straight grassland or agricultural crops. Sharp gradients in slope, surface aspect, and soil moisture are required to promote structurally diverse vegetation. To accomplish this, operators should incorporate diverse slopes, surface undulations, minor depressions, swales, convoluted drainageways and rock piles. Generally, the more diverse the plant and animal composition on the reclaimed area, the more stable the system is and the more chance that something will survive climatic extremes like drought, freezing temperatures or prolonged heavy snowfall.

The reclamation plan should present a statement of the reclamation goal and a timetable for achieving that goal. Revegetation should include native plant species, preferably a mixture of some of those species on site prior to mining. Seed mixtures will have to be tailored to soil and topography - one seed mixture may not suffice throughout a large site. Topographic and plant species diversity are both essential to replace wildlife habitat. Aquatic habitat within streams supporting fish and stock ponds used by wildlife should be restored.

Wildlife reclamation and enhancement measures planned by the applicant should be explained, not just identified, though the applicant has the option to alter plans as material availability and technology change. Reclamation plan changes may be proposed in permit renewal applications or by permit revision.

Suggested reclamation and enhancement practices include restoration of diverse land forms, direct topsoil replacement, shrub and tree transplants, nest structures, rock pile construction, snags and brush piles, water source development, stream rehabilitation (fish habitat structures, pools, riffles, etc.), riparian zone restoration, exclosure fencing of livestock impoundment headwaters and riparian zones, creation of lakes suitable for fisheries, and where variances can be obtained, development of highwalls to simulate natural rimrocks. Operators are encouraged to investigate other techniques as well.

Proposed locations of habitat components including seed mixtures, should be plotted on a topographic map. This will allow comparison with premining habitat interspersion. An example map can be obtained from DEQ-LQD or the Wyoming Game and Fish Department.

II. Inventory Techniques

A. Suggested Techniques

Objectives of the techniques discussed below are to describe major habitat types and important habitat components, to determine use of the site by important wildlife species, and to determine overall wildlife diversity on site. It is recommended that techniques for most species follow methods discussed in Wildlife Management Techniques (1980), the Wildlife Society, or Handbook or Biological Techniques (1982), Wyoming Game and Fish Department.

a. Vegetation

Vegetation analysis techniques contained in DEQ Guideline #2 are sufficient for wildlife habitat evaluation. Black and white photographs of each vegetation or habitat type sampled for wildlife should be included. Photographs should be original prints, not Xerox copies.

b. Habitat Types

Determination of habitat types should be made by a wildlife biologist. The major habitats generally correspond to identified vegetation types. Some physical habitats will be extensive enough to warrant sampling for wildlife as well. These types include streams, impoundments, playas, rimrocks, rough breaks, ravines, and other features (see Considerations for Wildlife in Mining and Reclamation (1976), Wyoming Game and Fish Department). Important habitat components such as rock outcrops, pools along streams, trees, and erosionally formed gullies are often interspersed within the major vegetation communities and these may substantially affect carrying capacity. The presence of such components should be indicated. Habitat types should follow first and second order classifications in the Wyoming Game and Fish Department's Wildlife Observation System.

c. Big Game

On large sites, aerial surveys may be required. These should follow the Handbook of Biological Techniques and should be augmented with ground searches, either by vehicle or on foot. Deer cannot be counted accurately from the air, particularly if conditions are not perfect or if a great deal of broken terrain, tall shrubs, or trees are present. Where discernible, sexes and ages should be noted for all animals seen. Because of the mobility of big game animals, surveys should include the permit area plus at least a two-mile perimeter. The existence of seasonal concentration areas should be documented.

d. Upland Game Birds

Acceptable methodologies are described in the Handbook of Biological Techniques. Both aerial surveys and ground searches may be required to locate breeding grounds on large sites. Small sites can be covered adequately by ground searches. Searches should be made for all upland game bird species known to occur in the vicinity of the permit area. It is often helpful to contact nearby landowners, or local Game and Fish Department personnel to locate breeding grounds. Once breeding grounds are found, the number of birds using the site should be determined. Production surveys should be conducted from a vehicle or on foot, to determine use of the study area by hens with young. Winter surveys should be made to determine the number of birds using the study area during that season. Upland game surveys should include the permit area and a 2-mile perimeter, because literature indicates that over 80 percent of sage grouse nesting occurs within 2 miles of a strutting ground. Consequently, a mine within 2 miles of a strutting ground could impact grouse even though the birds are not breeding on-site.

e. Waterfowl and Shorebirds

Waterfowl and shorebirds should be censused on all surface waters within the permit area including impoundments, streams, intermittent pools, and playas. Species composition and numbers using the permit area seasonally should be determined. Both breeding pair and brood counts should be conducted by standard waterfowl census techniques.

f. Raptors

Raptor Guidelines should be obtained from the Wyoming Game and Fish Department for appropriate survey techniques. Locations of raptor nests, feeding areas, and any roosting sites should be determined. Nests should be located during aerial flights when possible. A separate flight specifically for raptors may be necessary over large permit areas because it is difficult to locate raptors and their nests while also looking for other species. Inconspicuous nests can be located during ground surveys. The number of young hatched in each territory should be determined, but extreme care should be taken not to unduly disturb nesting birds, particularly early in the incubation period. Surveys should include the permit area and a two-mile perimeter. For raptors which may range 10-15 miles from a nest or roost, this is minimal. If raptor nests are located on the study area, the applicant should contact the U.S.F.W.S., Office of Ecological Services, to determine which nests are likely to be disturbed, to obtain the necessary permits, and to develop appropriate mitigation plans. The outcome of this consultation, along with a description of mitigation measures, should appear in the Mine Plan. Attached at the end of this guideline (Appendix B) is the mitigation program recommended by the U.S.F.W.S.

g. Passerine Birds

Nongame bird surveys should be conducted in each vegetation type, and in each major physical habitat. Acceptable methods include belt transects in most habitat types or point transects in riparian habitat. All surveys must be stratified by vegetation type, with at least two transects per type. Some transects should overlap two habitat types to determine species occurring in habitat edges. Starting points and orientation of transects should be randomly selected. If stratified random sampling is used, sample transects can be located in areas without the observer biasing selection of locations. Surveys should ideally be conducted on three consecutive days, then again one to two weeks later, to take into account temporal variation and weather effects on bird activities.

Each belt transect should be 100 m wide, but in denser or narrower habitats the width may be adjusted for better coverage. The total transect length should be 1,000 m (2,000 m per habitat type) but may consist of smaller segments totalling 1,000 m where the configuration of the habitat will not allow a continuous 1,000 m transect. Data for each segment should be recorded separately. The boundaries of belts should be marked so that observers can determine whether or not a bird is within a given belt. The observer walks the centerline and records all birds seen and heard within the belt. The time taken to walk the transect should also be recorded. Count periods should begin within 0.5 hours of local sunrise and not continue beyond 9:30 A.M.

Point transects should be used in riparian habitat, except that which is unusually narrow. The observer walks from point to point, stopping to listen and observe birds with 50 m of each point for 5 minutes. Points should be at least 100 m apart to avoid double counting. Transects can vary in length depending upon the size of habitat to be sampled. Where possible a 1,000 m transect is preferred.

h. Other Mammals

Small mammal occurrence should be determined by trapping along transects which have been randomly located. A sampling effort totalling 500 trap nights should be conducted over a 4 day period in each habitat type. Some transects or plots should overlap 2 habitat types to sample mammals occurring in habitat edges. Clusters of traps should be used to sample special habitat features such as rimrocks and pond edges. Traps should be a mixture of live traps, mouse traps, rat traps, and pitfall traps, with 1 live trap, 1 rat trap, and 2 mouse traps, at each station. Baits should be a combination of peanut butter, oatmeal, raisins, and animal fat. Transect length can vary according to the size of the habitat sampled, as long as the goal of 500 trap nights per vegetation type is reached. Less trap nights may be used in a special habitat. Trap stations should be at least 15 m apart. At least 5 pitfall traps should be placed along each transect in locations such as runways where the probability of capturing something is greatest. Traps should be set in the evening, checked, and reset the next morning, then again in the evening. Each 24 hour period is a trap night. All captured animals should be killed or removed from the area to prevent recaptures. Trapping can be done any time from May through July. This ensures capture of animals which begin hibernation very early. Data is reported as species caught and relative abundance (animals/100 trap nights) of each species in each habitat type.

Occurrence of medium-sized mammals can be determined from sign or observation. Lagomorph abundance should be determined by means of a walking transect through the best rabbit habitat on the permit area. Transects should be run on two consecutive nights at dusk, when there is no precipitation and the wind is no stronger than 15 mph. Data should be reported as the number of rabbits seen per standard transect length.

Predators and other medium sized mammals can be located by walking the permit area and looking for the animals or their sign. The goal is to document species occurrence.

i. Endangered Species and State-listed Rare Species

If prairie dogs occur on or within 1 mile of the permit area, the density of active prairie dog holes in each town should be determined and a ferret search should be conducted. The ferret search should follow techniques described in the most current U.S.F.W.S guidelines and the "Handbook of Methods for Locating Black-footed Ferrets, January 1984," available from the Wyoming BLM and WGFD. Appropriate survey techniques should be determined by consulting the U.S.F.W.S. Endangered Species Office in Helena, Montana. Searches should be conducted in each prairie dog town during baseline studies and again in each existing or newly colonized town within 1 year prior to disturbance of that town. Results must be submitted to OSM for clearance prior to disturbance. The occurrence of other federally listed rare or endangered species or species that are rare in Wyoming should be determined during the course of other field work. Surveys should include all lands within 2 miles of the permit area. State-listed rare species are contained in Current Status and Inventory of Wildlife in Wyoming (1977), Wyoming Game and Fish Department, Cheyenne. The occurrence of wintering bald and golden eagles should be evaluated by means of aerial or ground searches of the mine site and a 2 mile perimeter.

j. Reptiles and Amphibians

Species occurrence should be determined by trapping, hand capture, observation, and identification of calls. Emphasis should be placed upon searching in likely habitats during the day. Drift fences are effective for collecting snakes and migrating amphibians. The biologist may capture a variety of amphibians by seining with dip nets along margins of ponds and wetlands. Turtles and water snakes may also be captured by this technique. Only specimens absolutely necessary for positive identification should be killed and preserved. Reptiles and amphibians can often be located, identified, and left unharmed - especially during the spring and early summer breeding season. Most frogs and toads can be identified by their calls. Special emphasis should be placed upon documenting the occurrence of high management priority species as described in Current Status and Inventory of Wildlife in Wyoming (1977).

A list of species known to occur in the state and their habitats can be found in Reptiles and Amphibians of Wyoming (1980).

k. Aquatic Sampling

If perennial streams supporting fish populations occur on the proposed permit area, an aquatic study should be conducted by a qualified fisheries biologist to develop biological and physical baseline descriptions. The level of detail required will depend on the quality of the stream(s) to be affected and the degree to which the stream(s) will be impacted. At a minimum, the composition of benthic and fish communities should be determined and the following physical information collected: stream length within the permit area, stream length to be impacted by mining, gradient, average monthly flows, numbers and average lengths of runs and riffles, average width, average depth, predominant substrate types, meander intervals, the number and average capacity of pools, and standard water quality parameters. References may be provided for any of this information which already appears in the hydrology section of the permit application. A qualitative description of riparian, emergent, and submerged vegetation should also be included.

Stream quality should be described according to the classification system of the Wyoming Game and Fish Department. On most areas under consideration for coal development, streams will either be unclassified or Class 5 (lowest quality) and data requirements will be minimal. No data need be collected from most livestock impoundments as these man-made structures are generally replaced with equally productive impoundments during reclamation. If an impoundment contains a recreationally important fishery prior to mining, the operator should contact the Wyoming Game and Fish Department to determine data collection requirements. Sampling recommendations for various stream types follow:

Stream Classes 1 & 2 (Highest Quality)

Fish: species occurrence, sample composition, length/weight frequency classes

Periphyton (artificial substrates): species occurrence, relative abundance, diversity, evenness

Periphyton (natural substrates): species occurrence, sample composition

Benthos: species occurrence, relative abundance, evenness, diversity, biotic condition index (Winget 1979, cited in GAWS Aquatic Surveys Handbook. USFWS)

Stream Classes 3 & 4 (Medium Quality)

Same as Classes 1 & 2, with periphyton data on artificial substrates deleted.

Stream Class 5 and Lower

Fish: species occurrence, sample composition

Benthos: species occurrence, relative abundance, biotic condition index

Methods:

a. Fish:

Larger specimens should be sampled by use of a 3/4 inch seine and smaller specimens with a 1/4 inch seine. Lengths and widths of seines will vary depending on size of the area to be sampled. Dip nets should be used to sample undercut banks, around rocks, aquatic vegetation, and other habitats difficult to sample with a seine. Use of an electrofishing gun is permitted where provided for in the scientific permit. A scientific permit is required and must be obtained through the Director, Wyoming Game and Fish Department. When dealing with larger rivers which are more difficult to sample, species occurrence and a general idea of species composition is sufficient. Game and Fish Department records are often helpful in such situations.

b. Periphyton:

Natural substrates should be scraped and organisms collected in a net placed immediately downstream. Individual organisms may also be picked from substrates. The latter approach to sampling will provide species occurrence data that may otherwise be lacking if only artificial substrates are used.

Artificial substrates (plates) should be used to provide samples for statistical analysis. The plates should be left submersed for 2 to 3 weeks during the summer, or for a period of time sufficient to permit colonization. It is recognized that communities sampled from artificial substrates will differ in composition from natural communities, but such samples may be replicated with greater reliability and will provide a better basis for comparing reclamation results to the premining situation.

c. Benthos:

Sampling should be accomplished with an Eckman dredge or Surber sampler.

d. Water Quality:

The water quality parameters to be measured will vary from case to case, depending upon specific water quality characteristics of the stream(s) and anticipated impacts of the mining operation. Analytic procedures are described in Standard Methods for the Examination of Water and Wastewater. (See "Appropriate Literature" at the end of this guideline).

Appendix D-9 should include an assessment of mining impacts on fish populations. The mine and reclamation plan should incorporate measures to minimize and avoid damages to fisheries.

B. Use of Game and Fish Department Data

Game and Fish Department data are public information and available to companies free of charge or for reproduction costs. Seasonal distribution information for big and small game has been summarized on 1/8" per mile or 1/2" per mile overlays for the 1:500,000 scale BLM State Land Status map or for BLM surface management quads, respectively. These maps may not provide sufficient detail to evaluate big game distribution on small mine sites, but are useful in selection of study sites and in determining seasonal use of potential sites by game animals. Copies of maps may be obtained from the Cheyenne Office of the Game and Fish Department. Available data can be obtained upon request from field personnel, Game and Fish Department district offices, or the Cheyenne Game and Fish Department Office. Data are also available from the Bureau of Land Management and the U.S. Forest Service.

III. Scientific Permits

Scientific permits are required to handle any wildlife species. Permits applicable to most baseline studies include those required for collecting fish, amphibians and reptiles, and for small mammal trapping. These can be obtained via a letter of request to the Assistant Chief Game Warden, (mammals and birds), or the Assistant Chief Fish Warden (fish and herps), State of Wyoming, Game and Fish Department, Cheyenne, WY 82002. The letter should state the time period, the location, the reason for trapping, the species to be trapped, and if removal is to occur, the number of individuals to be removed. A report must be submitted at the end of the calendar year for which the permit is valid. The report should include species trapped and numbers, and locations to the nearest 1/4 section. Failure to submit a report is grounds for denying renewal of the scientific permit.

IV. Appropriate Federal Laws

Companies should be aware of the provisions of the Bald Eagle Act, amended in 1973, which protects bald and golden eagles, their nests, young and eggs. The U.S. Fish and Wildlife Service, the Wyoming Game and Fish Department, and the appropriate land management agency on federal land must be consulted prior to disturbance of eagles or their nests. Disturbances would include any activity conducted close enough to a nest site that the productivity of a breeding pair might be affected. The most direct disturbance would be physical destruction of the nest site. Power lines should be designed to prevent eagle electrocution. The Endangered Species Act of 1973 protects rare and endangered species of wildlife. Those species on the most current list should receive special attention in premining assessments and in monitoring activities.

V. Monitoring

Since monitoring is intended to evaluate wildlife problems on permit areas, there is no need for blanket monitoring of all species. Monitoring will be tailored to individual mines. For example, where there are large numbers of antelope, where a migration route is bisected by a mine, or where there are several grouse leks on the mine site, monitoring will be needed. These studies will be designed to obtain data in sufficient detail to evaluate the effect of mining on the wildlife species in question and to develop mitigation proposals. Monitoring studies will nearly always be of longer duration than the baseline study.

Proposed monitoring plans should be described within the mine plan.

If further information is needed concerning these guidelines, contact:

Game and Fish Department
Cheyenne, WY 82002
Phone: (307) 777-7604, 777-7605, or 777-7686

APPENDIX

A. Data Presentation in Appendix D-9

Data presentation in the wildlife section of the mine plan should approximate the following scheme:

1. Introduction

Two types of information should appear in the introduction. The first is a complete description of the baseline study area including its location and size. The second is a complete list of individuals and agencies responsible for data collection or consulted to obtain existing data. Specific names of individuals associated with consulting firms and state agencies should be provided. Names of company personnel who collected data need not be listed if the name of a responsible individual to whom inquiries may be sent is provided. Names of the person or persons responsible for assembling the baseline report should be provided.

2. Habitat Description

Habitat should be described both in terms of the major (physical and vegetative) types and the components (rock outcrops, gullies, landform features, water sources, trees, etc.) which affect carrying capacity within each major type. The amount (acreage, density, number, length--as appropriate) of each habitat component and the proportion of each to be disturbed should be tabulated. The interspersion of important habitats and habitat components on the permit area should be depicted on a topographic map of major vegetation communities. Habitat types should follow the first and second order classifications in the Wildlife Observation System used by the Wyoming Game and Fish Department.

3. Species Lists

A list of wildlife species that potentially occur on the permit area should be provided, and species actually seen on the site should be indicated with an asterisk.

4. Methods and Results

Methods used to sample each faunal group should be described at the beginning of the discussion of results for that group. For example, methods used to sample big game should precede the discussion of big game results. Sufficient detail should be provided so the sample could be replicated by another investigator, or a methods description within the literature should be cited. If data are taken from another baseline study, a description of methods used in that study should be included. The discussion of methods should include the intensity of sampling and conditions under which sampling was conducted in each habitat type, and the sample locations should be plotted on a topographic map. When sampling of a particular group of animals has been deleted by prior agreement, a statement to that effect should replace the methods section for that group and the results section should be deleted.

Results and discussion should follow the methods section for each group of animals. It is recommended that baseline data for each group be recorded on the Wyoming Game and Fish Department's Wildlife Observation Forms and copies sent to the area game biologist.

B. U.S. Fish and Wildlife Service Mitigation Program - Raptors and Migratory Bird Species of High Federal Interest.

Migratory Birds of High Federal Interest (MBHFI)

Several avian species are considered migratory birds of high federal interest and as such, are afforded protection under Chapter II, Section 3.b.(4)(b)(ii) and Section 3.a.(6)(e) of the 1981 Land Quality Rules and Regulations.

The permittee shall survey the permit area and land within 1/2 mile for occurrence of species listed as migratory birds of high federal interest and for important habitat types such as nest sites, breeding areas, or staging areas essential for continued survival. If such habitat is identified, the applicant must develop a habitat recovery and replacement plan for protection or enhancement of populations of these species, if they will be affected by habitat loss or displacement due to mine-related activities. The plan must be developed in consultation with, and approved by, the U.S. Fish and Wildlife Service, the Office of Surface Mining, the State of Wyoming, and the surface management agency. Until a mitigation plan is developed and approved, mine-related activities may not cause physical disturbance to a nest site nor may any major surface disturbances be conducted within important habitat identified through the consultation process.

Raptors in General

The following condition shall be specified whenever mine activities could potentially affect the nest of any raptor species:

Prior to permit^{c} approval, and each subsequent renewal, amendment or revision, the operator must consult the U.S. Fish and Wildlife Service to develop (or update) a raptor protection/mitigation plan. The operator shall provide the location, current status, and reproductive history of each nest on and within two miles of the permit area. The location of each nest in relation to mine disturbance shall be illustrated on a map showing at a minimum, the five year mine progression, and indicating the types of disturbance involved. The U.S. Fish and Wildlife Service shall determine which nests will likely be affected, and monitoring and/or mitigation requirements. The outcome of this consultation, along with a U.S.F.W.S. letter of approval shall be submitted with the permit application or renewal document. If U.S. Forest Service lands are involved, the mitigation plan must be approved by that agency as well. In the event that any new nests are discovered on or within one mile of the permit site during the course of the mining, the U.S. Fish and Wildlife Service shall be consulted to determine if mitigation requirements are necessary. The "take" of a raptor nest with eggs or young should be considered only when no other alternative exists, and after obtaining a special purpose permit from the U.S.F.W.S. The "take" of an inactive nest will also require a special purpose permit ("take" is defined to mean pursue, shoot, shoot at, wound, kill, capture, trap, collect, molest, or disturb).

C. Appropriate Literature

American Public Health Association, American Water Works Association, and Water Pollution Control Federation. 1976. Standard Methods for the Examination of Water and Wastewater. American Public Health Association. Washington, D.C. 1193 pp.

Baxter, G.T., and M.D. Stone. 1980. Reptiles and Amphibians of Wyoming. Wyoming Game and Fish Dept. 137 pp.

Burt, W.H. and R.P. Grossenheider. 1976. A field guide to the mammals. Riverside Press, Cambridge. 284 pp.

Clark, T.W., T.M. Campbell III, M.H. Schroeder, and L. Richardson. 1983. Handbook of Methods for Locating Black-footed Ferrets, January 1984. BLM Wildl. Tech. Bul. No. 1. Cheyenne, Wyoming. 55 pp.

Dorn, J. 1978. Wyoming ornithology, a history and bibliography. Wyoming Game and Fish Department and U.S. Bureau of Land Management. 371 pp.

Findholt, S., B. Oakleaf and B. Long. 1981. Wyoming Mammal Atlas. Wyoming Game and Fish Dept. Cheyenne. 20 pp.

Fyfe, R.W. and R.R. Olendorff. 1976. Minimizing the dangers of nesting studies to raptors and other sensitive species. Canadian Wildlife Service Occasional Paper No. 23. 17 pp.

Henderson, F.B., P.F. Springer, and R. Adrian. 1969. The black-footed ferret in South Dakota. S. Dakota Dept. Game, Fish and Parks, Pierre. 37 pp.

Hickey, J.J. and S.A. Mikol. 1979. Estimating breeding-bird densities on coal lands in Montana and Wyoming. U.S. Fish and Wildlife Service, WELUT, Ft. Collins, Co. 181 pp.

Long, C.A. 1965. The mammals of Wyoming. U. of Kansas Publs. Museum of Natural History. 14(18):493-758.

Oakleaf, R., H. Downing, B. Raynes, M. Raynes, and O. Scott. 1979. Wyoming Avian Atlas, Wyoming Game and Fish Dept. 67 pp.

Olendorff, R.R., A.D. Miller, and R.N. Lehman. 1981. Suggested practices for raptor protection on powerlines - the State of the Art in 1981. Raptor Res. Rep. No. 4, Raptor Research Foundation, Inc. Univ. Minn., St. Paul. 111 pp.

Postupalsky, S. 1974. Raptor reproductive success: some problems with methods, criteria and terminology. Pages 21-31 IN R.N. Hammerstrom Jr., B.E. Harrell and R.R. Olendorff, eds., Management of raptors. Proc. Conf. Raptor Conser. Tech., Raptor Res. Rep. No. 2 146 pp.

Robbins, C.S., B. Bruun, H.S. Zim, and A. Singer. 1966. Birds of North America. Golden Press. 340 pp.

Rothwell, R., G. Skutches, J. Straw, C. Sax, and H. Harju. 1978. A partial bibliography of the mammals of Wyoming and adjacent states. Wyoming Game and Fish Department and U.S. Bureau of Land Management. 172 pp.

Tessmann, S.A. 1984. Habitat reclamation procedures for surface coal mines in Wyoming in R.D. Comer, J.M. Merina, J.W. Monarch, C. Pustmueller, M. Stalmaster, J. Todd, and W. Wright, Eds. Issues and Technology in the Management of Impacted Western Wildlife. Proc. Symp., Thorne Ecological Institute. Boulder, Colorado. 250 pp.

The Wildlife Society. 1980. Wildlife management techniques. Wildlife Society, Washington, D.C.

Winget, R.N. and F.A. Mangum. 1979. Biotic Condition Index: Integrated Biological, Physical, and Chemical Stream Parameters for Management. USDA, Forest Service, Provo, Utah 84601 51 pp.

Udvardy, M.D.F. 1977. The Audubon Society Field Guide to North American Birds, Western Region. Knopf, New York. 853 pp.

Whitaker, J.O. 1980. The Audubon Society Field Guide to North American Mammals. Knopf, New York. 745 pp.

Wyoming Game and Fish Department. 1976. Considerations for wildlife in mining and reclamation. Cheyenne.

______________________________. 1982. Handbook of biological techniques.

______________________________. 1980. Wildlife Observation System User's Manual. 39 pp.

GUIDELINES FOR DEVELOPMENT OF FISH AND WILDLIFE INFORMATION FOR SURFACE MINING IN COLORADO

Allen F. Whittaker
Colorado Division of Wildlife
1982

PREFACE

The Surface Mining Control and Reclamation Act of 1977 (P.L. 95-87) and its pursuant regulations; and the Colorado Surface Coal Mining Reclamation Act (34-33-101 et seq.) and pursuant regulations dictate the wildlife be considered and protected throughout all phases of mining.

This handbook (guidelines) is designed to aid the coal operator and/or his environmental consultant in wildlife and related environmental baseline data collection in the preparation of a Fish and Wildlife Plan (mitigation for wildlife habitat losses during mining) and in the preparation of a final reclamation and land use plan which will benefit the state's wildlife resources.

This handbook is appropriate for premine data collection, mitigation and reclamation for any surface disturbances caused by the mining industry and is intended for use by planners of such projects.

The Colorado Division of Wildlife has been involved in the management of wildlife habitats for many years. The DOW has acquired and assembled a number of data sources concerning wildlife and their habitats which operators and consultants will find helpful prior to initiating field surveys. Among the data sources are:

1. The Wildlife Habitat Inventory System (WHIS). This is a computerized geo-based data bank of wildlife populations and their habitats. This system is based in the DOW Denver Office at 6060 Broadway. This system can be queried for tabular and geographic wildlife information from either the Denver office computer terminal or the terminals located in the four DOW regional offices. The information is being updated constantly and includes geographic presentation of winter ranges, critical winter ranges, reproduction areas, migration routes, and critical habitats for Threatened and Endangered species. The system also contains a large number of habitat descriptive parameters for streams and lakes which support a fishery resource.
2. The Colorado Latilong Distribution Studies -- one for mammals, one for birds, and one for reptiles and amphibians. These studies separate the state into 28 equal geographic blocks and lists the status and abundance of the various wildlife species inhabiting each block. The studies further list the habitat types in which both breeding and non-breeding populations are known to occur. These studies are available at the Denver office of the DOW.
3. Essential Habitat for Threatened and Endangered Wildlife in Colorado. This manual lists the various T&E species found in the state, describes their essential habitat, habitat requirements and the geographic location of these habitats. This publication is available at the Denver office of the DOW.
4. The Stream Data Base -- combined with the WHIS. This computerized file contains 180 items on 3,124 different streams or stream segments, including flow, gradient, water chemistry, and fishes present. It is accessible through the Division's Denver and four regional offices.
5. The DOW's Research Section has produced many special publications dealing with wildlife and their habitats. Included are technical publications, special reports, outdoor facts and Division reports all of which are available at the Division's Denver and Fort Collins offices. A complete list of titles is contained in Appendix A.

6. The DOW routinely acquires data concerning wildlife numbers, abundance, and habitat utilization for its ongoing wildlife management program. These data are available at the Division's four regional offices.

Additionally, the Division of Wildlife employs many experts on the various aspects of wildlife ecology and management. These individuals can provide technical assistance and review of various mine plans and projects. It is imperative that Division of Wildlife sources be consulted early in the mine planning process to prevent unneeded field work and so that wildlife interests can be economically incorporated into the mining and reclamation plans.

Premine Data Collection

Scope -- This section establishes guidelines for collection of premine wildlife and habitat data which ensure an adequate data base for wildlife mitigation during mining and restoration during and after reclamation. It must be recognized that wildlife species inhabiting the permit area are extremely dependent upon the vegetation found thereon. Thus, it may be convenient to map wildlife habitat features as a part of the vegetation mapping process. Habitat and vegetation maps shall include sufficient adjacent areas where effects on wildlife resources, due to the mine operation, may reasonably be expected to occur. The Division of Wildlife recommends that an area at least one-quarter mile wide, around the permit area, be mapped for its wildlife habitats.

Wildlife data shall include:

1. An inventory of species present on the permit area and adjacent areas, giving their relative abundance, relative importance to the ecosystem and seasonal occurrence in the various vegetation communities, and population status (i.e. abundant, common, peripheral).
2. A list of Threatened and Endangered species, if any, which inhabit the permit area or adjacent areas or which may be affected by the proposed mine operation.

The applicant shall determine which select wildlife species will be severely and moderately impacted by the proposed mine operation and shall prepare detailed habitat maps for these species. Additionally the applicant should determine which species will be slightly impacted and those which can be expected to be beneficially impacted by the proposed operation. A narrative of these slight and beneficial impacts should follow.

These select species should meet one or more of the following characteristics:

a. Species should have positive economic, social, educational, or ecological values.
b. A species designated as an official state or federal animal; i.e., bighorn sheep, lark bunting, bald eagle.
c. A species on an official federal or state list of Threatened or Endangered species.
d. A species with stenotopic habitat requirements.
e. The species habitat requirements and distribution should be known well enough that it can be mapped.
f. The species has a unique role in the ecological system of the permit area.

Terrestrial Habitats -- These detailed habitat maps for the select species shall be of a scale of 1:6000 or larger and shall indicate:

1. Plant species in each of the plant communities. It is recommended that plant communities be described as Herrington, Manual of the Plants of Colorado.
2. Season of wildlife use by species.
3. Reproduction areas such as elk calving areas, sage grouse strutting grounds and raptor rest sites.
4. Migration routes.
5. Winter range and critical winter range wintering species. These maps should include a measure of use such as animal unit months determined by pellet group counts, the condition and trend of the range plants, present utilization of browse species, and forage production by browse species.
6. Riparian areas showing extent of the riparian effect and plant species contained therein.
7. Competing uses of wildlife habitats, including but not limited to livestock, razing, recreation, farming, and proposed postmining land use.

8. Wildlife concentration and staging areas.
9. Wildlife shelter or cover areas.
10. Special habitat areas such as dead trees, or rimrock or ponds.

Aquatic Habitats -- Any permanent stream or lake which may be affected by the mining operation should be mapped and described by the following parameters:

1. Stream flow in cubic feet per second, taken before and after spring runoff.
2. Stream gradient.
3. Identification of fish spawning areas, of gravel beds of 1/4 inch to 3/4 inch gravel size.
4. Fish holding areas or large deep pools and undercut banks.
5. A meander factor.
6. Sallow nursery areas; i.e., backwaters having emergent vegetation.
7. Areas of streamside woody vegetation.
8. Areas of little use to fish such as silt-filled pools and gravel bars.

It is recognized that some of these parameters may be described under the hydrology section to the permit application. If such is the case, the parameter may be referenced to the appropriate section. Aquatic data need not be collected in intermittent or ephemeral streams.

FISH AND WILDLIFE PLAN

A Fish and Wildlife Plan shall be developed to comply with MLRD regulation number 4.18. The applicant is advised and encouraged to contact the Division of Wildlife at this stage of the application development.

Since wildlife habitat conditions and specific needs vary widely throughout the state, it will benefit the applicant to contact the Colorado Divison of Wildlife for assistance in tailoring the plan to the specific needs of the mine site. The applicant should contact the Division's Denver office for assistance.

It should be the goal of the Fish and Wildlife Plan to substantially mitigate the negative impacts to the select wildlife species identified in the premine data collection process while mining occurs, and enhance wildlife values where practicable.

For example, if it is determined that the mine will alter or destroy big game and sage grouse winter range, vegetation manipulation and/or fertilization, in areas adjacent to the mine site, to enhance forage production for displaced animals, may be recommended. Similarly, elimination or reduction of livestock grazing can be an effective method of enhancing forage production for wildlife in the vicinity of the mine.

A variety of wildlife habitat management techniques exist to enhance wildlife habitat features. These are described in detail in:

GUIDELINES TO HABITAT MODIFICATION TO BENEFIT WILDLIFE

Available: Colorado Division of Wildlife
6060 Broadway
Denver, CO 80216

MITIGATION OF IMPACTS TO MULE DEER AND ELK
FROM ENERGY DEVELOPMENT IN NORTHWEST COLORADO

Available: Habitat Resources Section
Colorado Division of Wildlife
6060 Broadway
Denver, CO 80216

BEST CURRENT PRACTICES FOR PROTECTING AND ENHANCING FISH AND WILDLIFE ON COAL SURFACE MINED LAND IN THE GREEN RIVER-HAWS FORK REGION
(in press)
Available: Western Energy and Lane Use Team
Drake Creekside Building
2625 Redwing Road
Fort Collins, CO 80526

A HANDBOOK FOR MEETING FISH AND WILDLIFE INFORMATION NEEDS TO SURFACE MINE COAL
FWS/OBS-79/48.3.5
Available: U. S. Fish and Wildlife Service
330 South Garrison
Lakewood, CO 80226
or
Denver Office of OSM

WESTERN RESERVOIR AND STREAM IMPROVEMENT HANDBOOK
FWS/OBS-78/56
Available: Western Energy and Land Use Team
Drake Creekside Building
2625 Redwing Road
Fort Collins, CO 80526

This is not meant to be complete list but an example of mitigation techniques for some classes of wildlife as follows:

1. Big game winter range -- areas of similar vegetative habitat off-site can be manipulated to produce more forage for wildlife. Techniques include:
    a. Roller-chopping, burning and cutting of decadent stands of mountain shrub species.
    b. Use of fertilizer and/or herbicides on decadent stands.
    c. Elimination or reduction of livestock grazing.
    d. A combination of the above.
2. Big game migration routes or concentration areas.
    a. Fencing to exclude big game from roads and/or guide them to an underpass.
    b. A reduction in traffic speed, particularly at dawn and dusk.
    c. "No firearm" policy or mass transit of workers will reduce illegal kill.
    d. Elmininate vegetation from sides of roads to increase visibility of crossing animals.

3. Elk calving areas -- presently under investigation.
    a. Create or enhance suitable calving habitat when such is defined by present research.
    b. Seasonally (May and June) avoid elk calving areas.
4. Sage and sharptail grouse strutting grounds.
    a. Create habitat (open grazing areas) suitable for strutting grounds off-site.
    b. Locate roads and facilities away from strutting grounds.
    c. Seasonally (February through May) avoid existing strutting grounds.
    d. Locate powerlines, which form raptor perches, away from line of sight with strutting grounds.
5. Raptor nesting sites.
    a. Being researched but generally install "fake" snags.
    b. If possible, leave an appropriate highwall, with holes in it, for golden eagle nesting.
    c. Seasonally avoid raptor nesting sites.
6. Non-game birds.
    a. Leave areas of old decadent trees intact.
    b. Develop marshy areas on stock ponds.
7. Small mammals and furbearers.
    a. A buffer zone should be left undisturbed along stream courses with woody riparian vegetation.
    b. Fence cattle from streambanks.
8. Sandhill Cranes.
    a. Seasonally avoid nesting and staging areas.
9. Streams.
    a. A bugger zone of undisturbed vegetation should be left along any stream whether intermittent of permanent.
    b. Sedimentation dams should be constructed to catch inadvertent sediments.

The Division of Wildlife realizes that wildlife mitigation is a relatively new science. It is presently researching numerous wildlife habitat improvement practices and the results will be made available when the projects are finished. The Division is receptive to other reasonable mitigation practices, recommended by an applicant, so long as they are monitored for their effacy.

APPENDIX D

Selected Baseline Methodology
and
Mitigation Manuals

APPENDIX D

Selected Baseline Methodology and Mitigation Manuals

Hinkle, C. R., R. E. Ambrose, and C. R. Wenzel. 1981. A handbook for meeting fish and wildlife information needs to surface mine coal - OSM Region V. FWS/OBS-79/48.3.5, USDI, Fish and Wildlife Service, Office of Biological Services, Washington, D.C., misc. pagings.

Institute for Land Rehabilitation. 1978. Rehabilitation of western wildlife habitat: a review. FWS/OBS-78/86. USDI, Fish and Wildlife Service, Western Energy and Land Use Team, Fort Collins, CO. 238 pp.

Moore, R. and T. Mills. 1977. An environmental quide to western surface mining, part two: impacts, mitigation and monitoring. FWS/OBS-78/04, USDI, Fish and Wildlife Service, Office of Biological Services, Western Energy and Land Use Team, Fort Collins, CO. misc. pagings.

Procter, B. R., R. W. Thompson, J. E. Bunin, K. E. Fucik, G. R. Tamin, E. G. Wolf. 1983. Practices for protecting and enhancing fish and wildlife on coal surface-mined land in the Green River - Hams Fork Region. FWS/OBS-83/09. USDI, Fish and Wildlife Service, Division of Biological Services, Washington, D.C. 242 pp.

Procter, B. R., R. W. Thompson, J. E. Bunin, K. E. Fucik, G. R. Tamin, E. G. Wolf. 1983. Practices for protecting and enhancing fish and wildlife on coal surface-mined land in the Powder River - Fort Union Region. FWS/OBS-83/10. USDI, Fish and Wildlife Service, Division of Biological Services, Washington, D.C. 246 pp.

Rutherford, W. H. and W. D. Snyder. 1983. Guidelines for habitat modification to benefit wildlife. DOW-R-M-83. Colorado Division of Wildlife, Denver, CO. 194 pp.

Swanson, G. A. 1979. The Mitigation Symposium. General Technical Report RM-65. USDA, Forest Service, Rocky Mountain Forest and Range Experiment Station, Fort Collins, CO. 684 pp.

States, J. B., P. T. Haug, T. G. Shoemaker, L. W. Reed, E. B. Reed. 1978. A systems approach to ecological baseline studies. FWS/OBS-78/21. USDI, Fish and Wildlife Service, Office of Biological Services, Fort Collins, CO. misc pagings.

Wyoming Game and Fish Department. 1977. Handbook of biological techniques. Wyoming Game and Fish Department, Cheyenne, WY. 393 pp.

APPENDIX E

Table of Survey Techniques
and
Associated Methodologies

APPENDIX E

Table of Survey Techniques and Associated Methodologies[1]

Survey Technique	Methodology
Terrestrial	
Aerial Survey	- Slow fixed-wing aircraft or helicopter low level flights usually along standardized transects or conforming to specific habitats or topographic features. Record observatoins by species, numbers, and habitat.
Vehicle/On-foot Surveys	- Slow travel by vehicle or on foot along standardized survey routes. Record observations by species, number, and habitat.
Pellet Group Surveys	- Record number of big game pellet groups intercepted by standardized transect or contained within standardized plots within different habitats.
Browse Evaluation	- Determine by standardized evaluation methods the degree of hedging of shrub and tree species by big game.
Stomach or Crop Contents or Fecal Material Analysis	- Laboratory analysis of contents to determine plant and animal material ingested.
Tagging/Radio-tracking Telemetry Studies	- Trap and distinctly tag or attach radio transmitter to a sample number of animals. Record tagged animals by location and habitat when observed during other surveys. Locate radio transmitter animals on a regular basis through use of two or more receivers and triangulation. Plot locations by habitat and individual located.
Scent Station Visitation Survey	- Establish standardized number of scent stations along standard (USFWS) route. Stations consist of scent attractant in the middle of a circle of soft, smooth soil. Tracks of predator visitor recorded by species, station, and habitat.
Trapping	- Set live "Sherman" or "Havahart" type traps or snap traps in random patterns, clusters, line transects, or grids in suitable habitats. Captures recorded by species, number, and habitat. Various statistical techniques or models used to estimate population size of small mammals.

APPENDIX E Continued

Survey Technique	Methodology
Night Spotlight Survey	- Slowly drive a predetermined route at night. With use of headlights and/or spotlight, record observations by species, number and habitat. Population indices calculated by dividing species numbers by acreage of corridor sampled by spotlight.
Strip Transects	- Slowly walk standardized transect in specific habitats and record species and numbers. Population indices calculated by dividing species numbers by acreage of corridor visually sampled.
Priaire Dog Town Surveys	- Estimate density of prairie dog burrows by various analytical techniques. Estimate acreage of town and plot extent and location of town on topographic maps.
Nest Survey	- Search all suitable habitat on foot with aid of binoculars or spotting scope. For inaccessible areas, search for nests by aerial survey.
Waterbird Surveys	- Make seasonal counts of all species and numbers occurring in all or a representative number of wetland or aquatic habitats. Record observations by survey area. For nest and brood surveys, search suitable habitat adjacent to wetlands or aquatic habitat and record nests and broods by location, species, and number.
Wetland Mapping and Evaluation	- Classify all wetlands by standard USFWS system. Map extent and location of all wetlands on topographic maps.
Lek Breeding Bird Counts	- Visit all known leks at least twice in early morning during spring breeding season. Record number of displaying males and females.
Crowing Call Counts	- Count and record number of pheasant crow calls in early morning for a set time period at standardized stops along a standardized vehicle route.
Variable Strip or Circular Plot Surveys	- Record species and numbers of birds by distance from observer along standardized transects or at predetermined points in all habitats. Population indices calculated for each species based on area sampled for that species.

APPENDIX E Continued

Survey Technique	Methodology
Spring Night Call Surveys	- In appropriate habitats, record amphibian calls by species and number for a standard time period in the evening.
Black-footed Ferret Surveys	- Use current USFWS guidelines to search prairie dog towns for ferret track or sign. Use same guidelines for conducting night spotlight surveys.
Incidental Observatons	- During all field activities, record all wildlife observations by species, number, location, and habitat.
Aquatic	
Seining and Electro-shocking	- Sample aquatic habitats using seine or electro-shocking equipment. Record fish species captured by number and size.
Aquatic Habitat Description	- Measure various standardized physical parameters and classify habitat using established classification systems.
Bottom Sampling	- Using standardized sampling equipment, take sample of bottom substrate. Using sieves and washing, separate out aquatic invertebrates. Classify by species and number.
Artificial or Natural Substrate Sampling	- Scrape or sample by other means representative samples from surface of natural bottom substrate. Separate out aquatic invertebrates and classify by species and number. For artificial substrate, secure standardized plates beneath water surface. Leave for standard time period and then scrape surface and separate out aquatic invertebrates. Classify by species and number.

[1] See Appendix C for a listing of manuals that describe methodologies of these and other survey techniques in detail.